METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 45 No. 271 MAY, 1952 Monthly: TWO SHILLINGS

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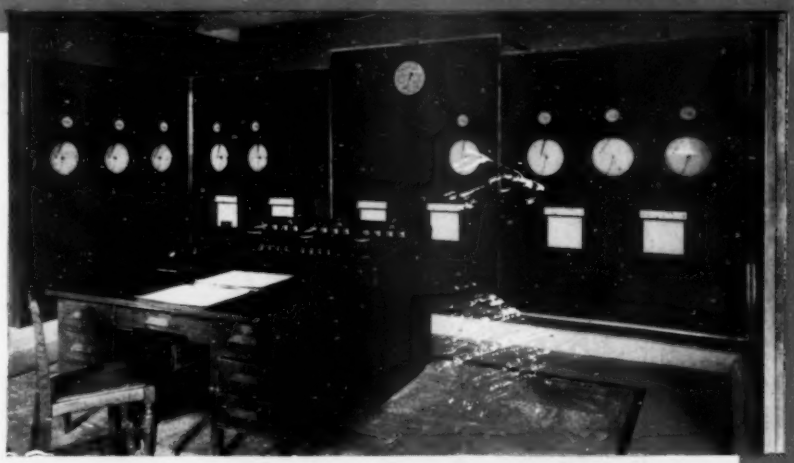

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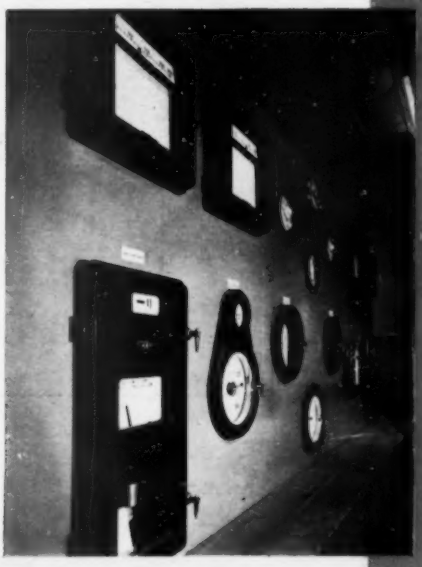

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Above: Control panel in Stove Control room.

Left: Control panel for Gas-cleaning plant.

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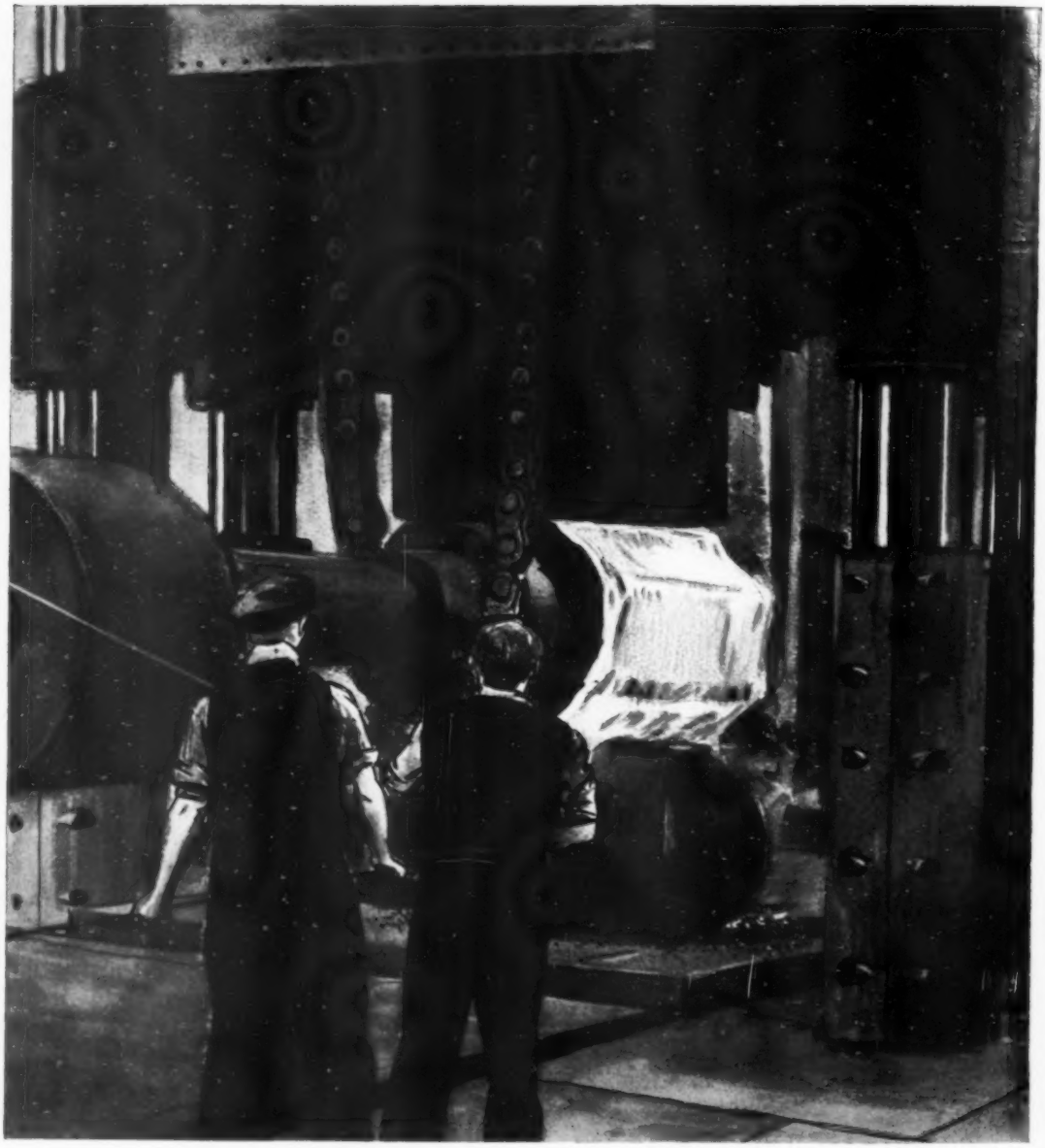

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

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Is Coal Too Cheap?

TO those who can recall how much a hundredweight of coal cost at the beginning of the century to-day's price seems almost astronomical by comparison. Each time that an increase is made there is a storm of protest on the grounds that, apart from its intrinsic effect on the cost of living, it has serious repercussions in that the resultant increases in the cost of transport, gas and electricity themselves affect the costs of producing and handling all capital and consumer goods, and so the inflationary spiral takes another upward turn. One might expect, therefore, universal approval for any steps taken to keep the price of coal down, and little support for the view of Mr. J. Walker, Director of The Morgan Crucible Co., Ltd., who, at a B.I.F. Industrial Gas Conference held in Birmingham earlier this month, stated that coal is sold too cheaply. But Mr. Walker is not alone in that view, for he gave it as one of six basic convictions which he said were widely held and often announced. Other two of his six beliefs provide the reason for this assessment of the value of coal, the first being that coal is not just a fuel but a valuable raw material forming the foundation of our whole economy. That being so, said Mr. Walker, it is a long-standing crime that so much of it is burnt raw, wasting the by-products, polluting the atmosphere and causing monstrous damage to assets which we now can never afford to replace.

There is, of course, much to be said on both sides. Whilst the stabilising of coal prices at a reasonable level would be of considerable assistance in checking inflationary tendencies, there is little doubt that, were coal prices considerably higher, we should be forced by economic circumstances to take steps to eliminate waste in all forms. Another aspect of the waste question was dealt with by Dr. G. E. Foxwell in the closing sections of his recent Presidential Address to the Institute of Fuel, on "Fuel Technology and Civilisation." In reviewing the British short-term fuel problem, Dr. Foxwell pointed out that, like our ancestors, we are faced with a population that, even allowing for the advances in agriculture and husbandry, is too great to be supported with the internal resources at our disposal. The economic solution is to produce more goods for sale abroad, as it has become plain that once again, as in the 18th and 19th centuries, only by every individual able to work producing to the limit of his or her abilities can we survive. As Mr. Churchill said recently, "If we cannot earn our living by the intense exertions of our strength, our genius and our craftsmanship, there will be no time to emigrate the redundant millions for whom no food is grown at home." But to achieve this productivity target more power will be needed and, until some other energy source becomes available in sufficient quantity, that means a greater demand for coal.

The National Coal Board's "Plan for Coal" envisages an increased output of 20 million tons, reaching a total annual production of 240 million tons in 1965. Foreseeable increases in home demand to meet the increased productivity suggest that not less than 260 million tons of coal will be needed by 1965, and some authorities suggest that requirements for the future will be nearer 300 million tons a year. As Dr. Foxwell pointed out, important economies in coal consumption can be made in the stages intermediate between raw coal and the useful application of the energy derived from it, and it is now generally accepted that these economies could be sufficient to bridge our immediate gap over the next few decades. The real difficulty—a difficulty much greater than is frequently understood—lies in providing the equipment necessary for the major economies on an economic basis. The importance of the fuel technologist in the struggle to bridge the gap lies obviously in his ability to take such action as lies within his power to use coal more effectively, and to advise those who have superior authority on what other measures should be taken. Failing a solution of the immediate fuel problem, the policy of full employment is impossible and hopes of staving off national disaster crumble to improbability. An all-out effort must be made to ensure that every operator who handles fuel is competent to do that work, and that every engineer concerned with fuel or power usage knows enough of fuel technology to ensure that at least no major source of economy within his purview is neglected, and that every business man is suitably impressed with the value of fuel-saving plant and the importance of fuel economy.

As heavy users of fuel and power for melting and fabricating, the metal industries have a special responsibility in this matter, particularly in view of the long-term problem involved. After all economies have been made, it is estimated that our future coal requirements are such that the estimated reserves of economically-minable coal will only last for another 150 years or so. It is more than likely, therefore, that within 100 years we shall be mining seams so much less economical to work than those in certain other countries that we shall be unable to compete in world markets with those goods requiring any considerable amount of energy for their production. British coals suitable for the production of metallurgical coke will have become exhausted at a much earlier date and the carbonising industries are even now seeking anxiously for new methods to use such coals as will remain available a generation hence.

Considerable progress has been made in fuel economy in the steel industry during the last few decades, but there must be no relaxation of effort if the fuel gap is to be bridged, particularly as the increased demand for coke consequent upon increased pig iron production will be accentuated in proportion to the amount of lean home ore used. And not only in the steel industry is there need for constant vigilance in the matter of fuel consumption—perhaps to a greater extent is it necessary in the smaller firms, whose consumption is small individually, but collectively represents no mean figure.

Some Experiments with Ductile Cast Iron

By C. C. Hodgson, A.Met., F.I.M. and C. S. Johnson, B.Sc., A.I.M.

Respectively, Chief Metallurgists, Leyland Motors Limited and West Yorkshire Foundries Limited

Much information has been published in recent years on the fundamentals of the production of spheroidal graphite cast irons. The present article, which records the results of an investigation designed to enable comparison to be made between such irons and blackheart malleable cast iron, deals with the production of the iron on laboratory and foundry scales, and with its mechanical properties in the annealed condition. In a subsequent article, some factors affecting the annealing and heat treatment of ductile cast iron will be discussed.

THIS record is a factual account of some of the work on ductile cast iron carried out by the authors during 1950. As no attempt has been made to enter into theoretical discussions, nor to correlate the results with those of other investigations, references are not made to the voluminous literature which has already grown up around ductile cast iron. The authors feel, however, that they should pay their tribute to the classical work so beautifully conducted by Morrogh and his collaborators at the B.C.I.R.A. in this country and to the work carried out in America and Europe, respectively, by the teams of the International Nickel Company and the Mond Nickel Company, on the magnesium treatment method for the production of ductile cast iron.

The present investigation was intended to provide information which would enable comparison to be made between ductile cast iron and blackheart malleable cast iron. The influence of raw materials on the response to nodularisation was examined and the relationship between chemical composition and mechanical properties of annealed ductile cast iron, under certain imposed conditions, was established. The investigation included a considerable programme of full-scale foundry tests made to establish the influence of melting methods and foundry technique. A number of machining tests form the natural conclusion to the work.

Materials

There is reason to believe that pig irons vary in their response to magnesium treatment, in that some materials do not respond well, although they would appear to be suitable, when judged by their chemical analysis (as usually reported). The authors have used a number of refined irons and pig irons in the course of this work, and the results obtained from some of them are reported. Re-carburising iron P.4634 (Table I) behaved particularly well and, in the laboratory experiments, this iron was used throughout as the base metal when the influence of other variables was being examined.

Additions of manganese and silicon were made in the form of ferro-manganese and ferro-silicon (75% silicon), phosphorus was added as high phosphorus pig iron, P.5582 (Table I), and carbon increase was achieved by the addition of graphite to the molten metal.

Laboratory melts were made on the three pig irons referred to in Table I, and on mixtures of these containing steel. The results obtained from P.5039 were fairly good, but on the other two they were poor. Some of the most outstanding results were obtained from melts based entirely on steel scrap and a number of these have been collected in Table II. Reference should also be made to Table XIII as the ductile irons listed there were also made from steel scrap.

TABLE I.—CHEMICAL COMPOSITION OF IRONS USED FOR THE PREPARATION OF EXPERIMENTAL CASTS

	Re-carburising Iron P.4634	Pig Iron P.5039	Pig Iron P.3472	Pig Iron P.5495	Pig Iron P.5582
Carbon %	3·65	3·90	4·06	4·20	3·55
Silicon %	0·04	1·60	3·05	1·70	2·92
Manganese %	0·15	0·58	0·31	0·90	0·89
Sulphur %	0·01	0·02	0·04	0·05	0·041
Phosphorus %	0·03	0·04	0·04	0·16	1·30
Nickel %	0·04*	0·10*	0·06	0·04*	
Chromium %	0·02*	0·14	0·10*	0·09	0·24
Copper %	0·12*	0·05*	0·05*	0·05*	
Molybdenum %	ND	0·01*	ND	0·01*	
Titanium %	ND	0·08	0·12	0·10	
Arsenic %	less than 0·02				
Vanadium %	ND	0·05*	0·08*	0·02*	
Magnesium %	P	P	P	ND	

* Determined spectrographically.
P. Indicates that the element was found to be present in very small amounts (spectrographically).
N.D. Indicates that the element was not detected when the material was examined spectrographically.

Each of the five casts recorded in Table II was made from a different quality or grade of steel scrap. The magnesium addition in all instances was 0·2%: preliminary work had shown that a fairly high magnesium addition was desirable in conjunction with steel scrap melts.

In addition to the elements listed in Table I the materials were examined spectrographically for a number of the more unusual elements. None of the following was detected: Al, Pb, Zn, Sb, Se, W, Co, Sn, Bi, B, Te, Ca.

The foundry melts were based entirely on selected steel scrap. Suitable refined pig iron was available but would have been much more expensive to use. Deep

TABLE II.—DUCTILE IRON MADE FROM STEEL SCRAP

Reference	114	142	143	146	156
Carbon %	2·75	2·92	2·86	2·88	3·00
Silicon %	2·41	1·97	2·00	2·00	2·13
Manganese %	0·16	0·14	0·09	0·11	0·04
Phosphorus %	0·04	0·02	0·02	0·02	0·03
Nickel %	1·37	1·26	1·32	1·22	1·24
Chromium %		0·04	0·04	0·06	
Molybdenum %		trace	trace	trace	
Magnesium %	0·11	0·08	0·07	0·08	0·11
Yield Stress—tons/sq. in.	24·2	20·2	21·1	20·6	21·2
Ultimate Tensile Stress—tons/sq. in.	30·1	27·7	28·0	28·4	28·0
Elongation %	19	23	23	23	24
Reduction of Area %	21	28	24	28	28
Izod Impact—ft. lb.	15	18	18	18	17
Brinell Hardness (H/10/3000)	159-166	143-146	146	143-146	143-146

TABLE III.—RELATIONSHIP BETWEEN IZOD IMPACT (STANDARD 0·45 IN. DIAMETER NOTCHED BAR) AND IMPACT TESTS ON UN-NOTCHED BARS (Average ft. lb.)

0·450 in. diameter Notched Bar	0·450 in. diameter Un-notched Bar	0·798 in. diameter Un-notched Bar
1	5	32
2	32	Unbroken
3	75	Unbroken
5	90	
6	99	
11	98	
16	Bent—Unbroken	

drawing steel tube scrap was employed mainly, in order to make sure of using a material of consistent quality and lowest phosphorus content practicable.

The adoption of basic cupola melting ensured an adequate carbon content in the resultant iron for satisfactory fluidity at the temperatures obtainable, and a satisfactorily low sulphur content for economy of magnesium alloy addition.

Silicon was added to the charge in the form of ferro-silicon briquettes for, while under the conditions of melting this was relatively expensive, the use of a 19% silicon special refined iron proved detrimental to the properties of the resultant iron after magnesium treatment.

Test Bars and Mechanical Testing

Test castings had the form and dimensions shown in Fig. 1 : by making three saw cuts these furnished four test bars suitable for machining. Tensile test pieces were machined to 0·564 in. diameter × 2 in. gauge length. The authors believe that confusion has been caused by the unsatisfactory reporting of impact tests made on ductile iron, and throughout their experiments they have used the 0·45 in. diameter bar and the standard Izod notch. A comparison of the results obtained from different forms of test is contained in Table III.

Melting, Treating and Casting in the Laboratory

A small high-frequency induction furnace was used for the laboratory experiments, the charges weighing about 18 lb. After melting, the metal was heated to a temperature of 1,400° C. before making the magnesium addition. When the reaction was complete, the melt was brought back to 1,400° C., "slagged off" and inoculated. The inoculant was usually in the form of 75% ferro-silicon of which sufficient was added to bring 0·75% silicon into the melt. All test bars were cast at 1,400° C., the time between adding the magnesium and casting the test bars being usually about four minutes.

Experiments were made to ascertain the influence of variations in the temperature of the metal when adding the magnesium alloy, and it was found that under the imposed conditions there was considerable latitude. A range of 100° C., from 1,400° to 1,500° C., produced no important difference in the final result. Similarly, there was little difference between the action of 75% ferro-silicon and S.M.Z. alloy. As results which were almost as good were obtained without any inoculation treatment, however, it seems likely that greater differences might be found in treating larger volumes of metal under foundry conditions.

The holding time after the magnesium addition was found to have a marked effect on both the shape of the graphite particles and the mechanical properties of the annealed iron, as will be seen from Table IV.

The melting conditions in the induction furnace caused considerable oxidation of manganese. Thus in

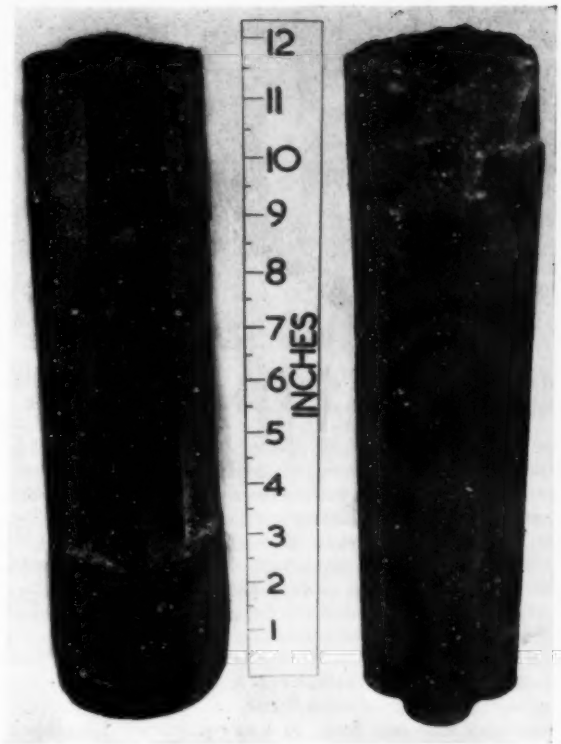

Fig. 1.—Test piece castings.

melting refined irons containing about 0·4% manganese the loss ranged from 17 to 27%, and with a hematite pig of about 0·6% manganese, the melting loss was from 24–34%.

Basic Cupola Melting of All-Steel Charges

The foundry melting plant consisted of a 30 in. internal diameter cupola with a gas-heated tea-pot-spout ladle, holding 10 cwt. of iron, mounted in front of the cupola for the magnesium treatment.

The cupola was of conventional design, apart from the provision of a deeper well in order to enable a substantial slag bulk to be carried in the furnace while operating with intermittent tapping, thus providing the maximum opportunity for desulphurisation. A rammed, stabilised dolomite lining was initially installed, but it was later replaced by a brick lining as the depth of fritting, even in the melting zone, was insufficient and the lining, therefore, lacked adequate mechanical strength.

A difficulty encountered was the heavy lining wear in the melting zone due to the method of operation, and

TABLE IV.—EFFECT OF HOLDING TIME AFTER MAGNESIUM TREATMENT

Holding Time after Magnesium Addition	2½ Minutes	10 Minutes
Photomicrograph	Fig. 2	Fig. 3
Yield Stress—tons/sq. in.	19·4	19·3
Ultimate Tensile Stress—tons/sq. in.	26·6	22·4
Elongation %	26	6
Reduction of Area %	32	
Izod Impact—ft. lb.	16	9
Brinell Hardness (H/10/3000)	149	133

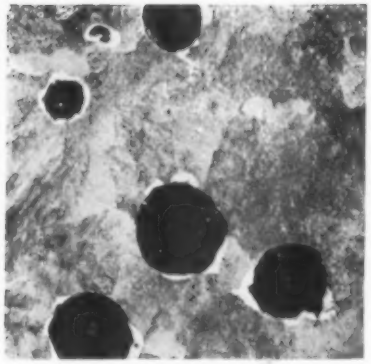

Fig. 2.—Ductile cast iron—held 2½ minutes after the magnesium addition. ×200

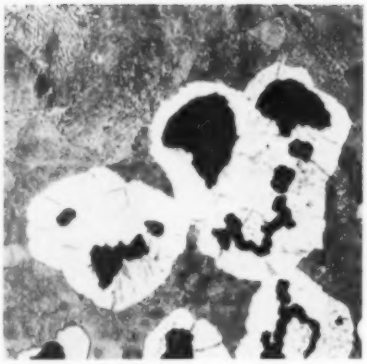

Fig. 3.—Ductile cast iron—held 10 minutes after the magnesium addition. ×200

the application of patching material was not easy owing to its lack of plasticity and adhesion. The need for some method of water cooling seemed to be indicated to minimise this expensive consumption of refractories.

The changes in composition during melting, particularly with respect to carbon and silicon contents, were very great and, as would be expected from this, the base metal analysis at the spout was more variable than is usual with more conventional cupola operation. Fortunately, fairly wide variations in the amounts of these particular elements were found to be permissible. For reasons mentioned later, it was considered desirable to avoid very high carbon contents and the basicity of the slag was, therefore, kept at a CaO/SiO_2 ratio of about 1·1, to limit carbon pick-up to some extent.

With 100% steel charges, and those which later included up to 60% runner and riser return scrap, the carbon contents obtained were mainly between 3·3 and 3·6% but in exceptional cases carbons as high as 4·1% and as low as 3·2% were obtained.

The silicon loss when using briquettes was very high at approximately 50%, with charges containing 2·2% silicon, but this figure was reduced to 26% loss on one cast where 12% of a 19% silicon special refined iron was used. Unfortunately, the use of this refined iron, even in such a small quantity, was detrimental in other respects, as indicated earlier.

The sulphur contents were satisfactorily low at between 0·02% and 0·05% in all but isolated instances, this being very much lower than would be expected from this type of charge in acid melting, i.e., the sulphur pick-up from the rather high coke charge (4·5 : 1 metal : coke ratio) used was, for all intents and purposes, prevented. The precaution of providing an adequate flux charge in the initial stages of the blow was necessary to counteract a tendency for high sulphur contents on the first few charges.

The melting loss of manganese was also higher than in acid practice, but in this case a low manganese content was an advantage from the annealing point of view.

The details appertaining to two typical casts from the basic cupola, one an all-steel charge and the other with 50% return scrap, are shown in Tables V and VI.

TABLE V.—TYPICAL CAST FROM 30-IN. I.D. BASIC CUPOLA MELTING ALL-STEEL CHARGE

Charge Details

100% Steel Scrap and Ferro-Silicon Briquettes.

	T.C.	Si	S	P	Mn
Charge Analysis into Furnace	0·13	2·52	0·05	0·032	0·43

Coke Charge .. .. 125 lb. to 5 cwt.
Coke Ratio .. .. 4·5 : 1
Limestone .. .. 32 lb.
Fluorspar .. .. 12 lb.
Double flux on bed.

Sample	Metal Analysis %			
	T.C.	Si	S	Mn
(First Tap)				
1	3·24	1·36	0·069	0·32
2	3·40	1·43	0·058	0·35
3	3·40	1·42	0·045	0·35
4	3·31	1·43	0·053	0·27
5	3·21	1·30	0·040	0·29
6	3·32	1·30	0·059	0·35
Average ..	3·31	1·37	0·051	0·32
Change ..	+3·18	−1·15		−0·11
% Change		−46%		−26%

	Slag Analysis					
	CaO/SiO_2	CaO	SiO_2	MgO	FeO	S
	1·03	33·3	32·3	9·40	0·74	0·71

Ladle Treatment

The cupola metal was tapped directly from the cupola into the treatment ladle which was lined with ganister.

The magnesium-treated iron was inoculated, after skimming, with 0·50% silicon, using 75% ferro-silicon, this material being preferred to SMZ, which gave a rather smaller amount of slag, but one which was more fluid and somewhat more difficult to remove.

Attempts were made to combine the two treatments by adding the inoculant to the treatment ladle before the completion of the magnesium reaction but, while the test bar properties after annealing were not impaired, in some cases there was a noticeable increase in the amount of cementite in thin and medium sectioned castings.

The temperature loss under the conditions prevailing during the double treatment was appreciable, and the casting temperatures were therefore lower than is usual in good, high-duty grey iron foundry practice. The resultant iron was reasonably fluid, however, and by cutting down to a minimum the time lost in transport it cast reasonably well.

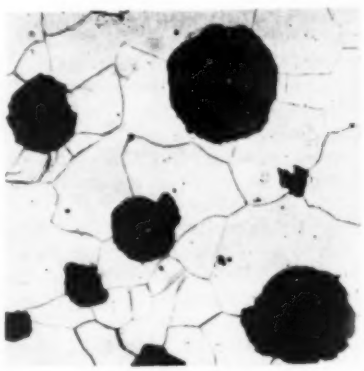

Fig. 4.—Ductile cast iron in the annealed condition. ×200

Production Control Procedure

For the purpose of the experimental production trials, the castings from each charge of treated metal were segregated by suitably marking and each batch held until the efficiency of the treatment had been confirmed. Rapid confirmation was obtained by microscopic examination of the "as cast" structure, and, in cases of doubt, by the spectrographic determination of magnesium. The control specimen used was a solid block, 3 in. × 4 in. × 2½ in. deep, with a ⅞ in. diameter peg projecting 1¼ in. from the centre of the bottom face. The peg could readily be broken off and the fractured surface polished for microscopic examination, the polished face being later sparked. The solid block furnished a specimen from which drillings for chemical analysis could be obtained.

This procedure was sufficiently foolproof without awaiting the annealed-test-bar mechanical test figures, but was dependent upon reasonably close control of composition in melting, and the use of satisfactory raw materials.

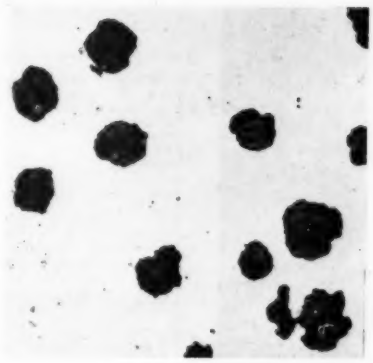

Fig. 5.—Annealed ductile cast iron containing less than 00·1% aluminium. Unetched. ×100

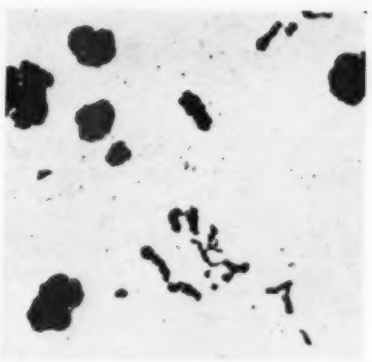

Fig. 6.—Annealed ductile cast iron containing 0·19% aluminium. Unetched. ×100

Casting Technique

The "castability" of the treated iron as regards fluidity, shrinkage characteristics, etc., was found to be as has been described in other papers on this subject, but the necessity for elaborate precautions to avoid slag inclusions in the castings needs further emphasis, in the opinion of the authors.

In addition to the liability for the presence of mechanically entrapped slag from the double treatment (if it had not been completely removed), turbulence in pouring caused further inclusions. It is suggested that these may be due to the oxidation of part of the magnesium content of the iron. This effect appeared to be proportional to the amount of magnesium present, and if this exceeded 0·1% it was most difficult to avoid the presence of such slag.

The presence of inclusions on the outside skin of the castings was not usually noticeable until they were reshot blasted after annealing.

Annealing of Test Bars and Castings

It has been stated in the introduction that the authors' chief object in carrying out these experiments was to assess the possibilities of ductile cast iron as an alternative to blackheart malleable cast iron; particular attention was, therefore, directed to the quality of toughness. All test bars were given a short anneal at 900° C. and cooled slowly in the furnace: the average cooling rate in the temperature interval 800°–650° C. was 0·25° per minute. A photomicrograph representative of the material (of low manganese content) in the annealed condition is shown in Fig. 4. Castings intended for machinability test were given a similar annealing treatment.

The Addition of Magnesium

An important factor in the production of ductile cast iron of good quality, particularly in the matter of reproducibility of results, was found to be the method of adding the magnesium-bearing alloy. Once a satisfactory method had been established this method was strictly followed, although that used for the laboratory crucible melts differed from the one used in the foundry for cupola-melted iron. The alloy used throughout for the addition of magnesium was obtained through the co-operation of The Mond Nickel Company; it was the nickel-magnesium alloy identified by that company as "No. 1 Alloy."

The amount of magnesium added may vary considerably without influencing the mechanical properties of annealed ductile cast iron, as can be seen from the results reported in Table VII, which contains the results of some laboratory high-frequency furnace melts. This observation refers to work using iron P. 4634 as a base and does not contradict the conclusion about magnesium additions to all-steel charges mentioned in a previous section.

The Influence of Chemical Composition on the Mechanical Properties of Annealed Ductile Cast Iron

Carbon: Carbon in the range 3·0–3·6% does not appear to exert any marked influence on the tensile and Izod values, but there is some evidence suggesting a

TABLE VI.—TYPICAL CAST FROM 30-IN. I.D. BASIC CUPOLA MELTING STEEL AND RETURN SCRAP

Charge Details

50% Steel Scrap.
50% Return Scrap (1·5% Si) and Ferro-Silicon Briquettes

	T.C	Si	S	P	Mn
Charge Analysis into Furnace	1·80	2·19	0·03	0·026	0·32

Coke .. .. .. 125 lb. to 5 cwt.
Coke Ratio.. .. 4·5 : 1.
Limestone .. .. 35 lb.
Fluorspar .. .. 6 lb.

Sample	Metal Analysis—%			
	T.C.	Si	S	Mn
(Second Tap)				
1	3·44	1·14	0·035	0·23
2	3·51	1·16	0·037	0·29
3	3·51	1·14	0·035	0·28
Average ..	3·48	1·15	0·035	0·27
Change ..	+1·68	—1·04		—0·05
% Change	+94%	—47·5		—18·5

	Slag Analysis					
	CaO/SiO_2	CaO	SiO_2	MgO	FeO	S
	1·17	39·4	33·8	7·70	1·06	0·47

Fig. 7.—A group of typical ductile iron castings.

trend towards reduced ductility at the upper end of this range. Table VIII.

Silicon: In the range 1·5–3·0%, this element causes a progressive hardening of the annealed iron, increasing the tensile stress from 24 to 32 tons/sq. in. Ductility is not noticeably affected but there is a sharp drop in the Izod value as the silicon increases. The maximum safe value should not exceed 2·5% if a good impact is to be assured. Table IX.

Manganese: The element manganese was found to have less effect than had been expected from a consideration of the results of previous work, but it would be advisable to place the upper limit at 0·3% if maximum toughness is to be obtained. (See Table X). It will probably be found to exert a more marked influence when quicker cooling rates are employed, or when subcritical annealing is used.

Phosphorus: There is a sharp drop in Izod value when the phosphorus exceeds 0·10%. The ultimate tensile stress increases as the phosphorus rises. (See Table XI).

TABLE VII.—THE EFFECT OF MAGNESIUM ADDITION ON THE MECHANICAL PROPERTIES OF ANNEALED DUCTILE CAST IRON

Magnesium Addition %	0·1	0·125	0·15	0·2
Carbon %	2·76	2·90	2·90	2·98
Silicon %	2·18	1·87	2·18	1·96
Manganese %	0·07		0·10	
Sulphur %	0·010			
Phosphorus %	0·030			
Nickel %	0·60		0·82	1·02
Magnesium %	0·03	0·05	0·04	0·07
Yield Stress—tons/sq. in.	18·7	18·5	19·6	20·2
Ultimate Tensile Stress—tons/sq. in.	25·6	26·0	26·5	26·9
Elongation %	20	27	21	25
Reduction of Area %	19	32	21·5	28
Izod Impact—ft. lb.	15	19	15	19
Brinell Hardness (H/10/3000)	134–137	124–131	134–140	131–134

TABLE VIII.—THE EFFECT OF VARIATION IN CARBON CONTENT ON THE MECHANICAL PROPERTIES OF ANNEALED DUCTILE CAST IRON

Carbon %	3·06	3·32	3·62	3·62	3·62
Silicon %	2·06	2·02	1·94	2·00	1·94
Manganese %	0·13				
Sulphur %	0·01				
Phosphorus %	0·03				
Nickel %	0·96	0·96	0·94	0·92	0·88
Magnesium %	0·09	0·10	0·11	0·09	0·10
Yield Stress—tons/sq. in.	19·4	18·2	18·4	18·2	17·6
Ultimate Tensile Stress—tons/sq. in.	26·6	26·1	25·5	24·9	24·8
Elongation %	26	23	24	15	12
Reduction of Area %	32	28	26	15	13
Izod Impact—ft. lb.	16	16	15	11	13
Brinell Hardness (H/10/3000)	149	143	134	134	131–134

TABLE IX.—THE EFFECT OF VARIATION IN SILICON CONTENT ON THE MECHANICAL PROPERTIES OF ANNEALED DUCTILE CAST IRON

Carbon %	3·25	3·05	3·06	3·07	3·00	3·07	3·03	3·1
Silicon %	1·48	1·77	2·06	2·29	2·46	2·64	3·04	3·2
Manganese %	0·11	0·14	0·13					
Sulphur %	0·01	0·01						
Phosphorus %	0·036	0·032	0·03					
Nickel %	0·78	0·82	0·96	0·88	0·88	0·86	0·82	0·8
Magnesium %	0·10	0·10	0·09	0·10	0·08	0·09	0·10	0·1
Yield Stress—tons/sq. in.	15·8	16·8	19·4	20·4	22·8	23·2	25·2	27·
Ultimate Tensile Stress—tons/sq. in.	24·2	25·4	26·6	28·1	29·7	30·0	32·0	32·
Elongation %	25	25	26	24	23	22	20	20
Reduction of Area %	34	38	32	28	28	28	24	24
Izod Impact—ft. lb.	18	17	16	15	13	11	5	3
Brinell Hardness (H/10/3000)	131	137	149	155	159	163	174	174

Minor Elements: The influence of the elements tin, lead, antimony, and arsenic can be seen from the results collected in Table XII. The cooling rate after annealing these specimens was slightly quicker than that used for the previous experiments. Subsequent work established that tin causes ductile iron to be very susceptible to cooling rate after annealing. Cooling the iron containing 0·09% tin at the slower rate previously used caused the Izod value to increase to 13 ft. lb. No such improvement through slower cooling occurred in the instances of lead and antimony.

Aluminium, up to 0·2%, appears to be without influence on the mechanical properties of the annealed iron. It did, however, influence the form of the graphite, much of which was not wholly spherulitic when aluminium was present. The mechanical test results for some of the aluminium experiments are given in Table XIII. These observations are based on laboratory melts of steel tube scrap with aluminium additions. The experiments recorded in the previous paragraph were, however, made on melts using refined iron P.4634.

Titanium was found to have a marked influence on the form of the graphite. An experimental cast of iron containing the usual amounts of carbon, silicon, and manganese and 0·18% titanium was made up from iron

TABLE X.—THE EFFECT OF VARIATION IN MANGANESE CONTENT ON THE MECHANICAL PROPERTIES OF ANNEALED DUCTILE CAST IRON

Carbon %	2·90	2·81	2·72	2·78	2·98	3·00	3·12
Silicon %	2·18	1·92	2·10	2·03	1·96	1·96	2·00
Manganese %	0·10	0·25	0·28	0·43	0·44	0·68	0·82
Sulphur %	0·01						
Phosphorus %	0·036						
Nickel %	0·82	0·90	0·84	0·92	0·96	0·94	0·91
Magnesium %	0·04	0·09	0·04	0·10	0·07	0·06	0·07
Yield Stress—tons/sq. in.	19·6	19·3	21·2	19·3	19·7	20·2	20·4
Ultimate Tensile Stress—tons/sq. in.	26·5	26·7	27·9	27·0	27·7	28·7	29·8
Elongation %	21	25	22	24	22	20	22
Reduction of Area %	21	32	24	24	24	20	23
Izod Impact—ft. lb.	15	17	15	14	15	13	12
Brinell Hardness (H/10/3000)	137	140	146	139	137	153	159

TABLE XI.—THE EFFECT OF VARIATION IN PHOSPHORUS CONTENT ON THE MECHANICAL PROPERTIES OF ANNEALED DUCTILE CAST IRON

Carbon %	2·90	2·78	3·03	3·06	3·17	2·92	3·25
Silicon %	2·18	1·92	1·98	2·00	2·02	2·02	2·02
Manganese %	0·10	0·11	0·20	0·14		0·26	0·28
Sulphur %	0·10						
Phosphorus %	0·036	0·05	0·11	0·14	0·16	0·19	0·31
Nickel %	0·82	0·66	0·88	0·80	0·94	0·74	0·92
Magnesium %	0·04	0·08	0·05	0·07	0·05	0·07	0·08
Yield Stress—tons/sq. in.	19·6	20·3	21·2	22·0	21·9	24·0	
Ultimate Tensile Stress—tons/sq. in.	26·5	26·9	28·8	28·1	29·8	30·8	
Elongation %	21	24	23	10	21	22	
Reduction of Area %	21	24	28	15	21	22	
Izod Impact—ft. lb.	15	16	11	6	6	3	1
Brinell Hardness (H/10/3000)	137	140	148	161	164	161	167

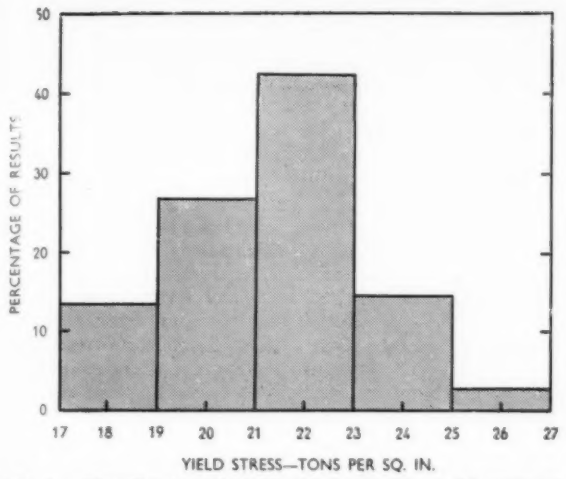

Fig. 8.—Distribution of yield stress results on 91 casts of cupola-melted annealed ductile cast iron

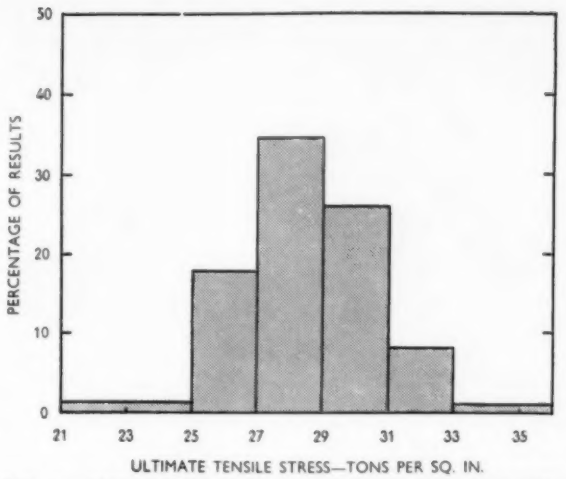

Fig. 9.—Distribution of ultimate tensile strength results on 91 casts of cupola-melted annealed ductile cast iron.

P.4634 to which ferro-silicon-titanium was added. A small portion only of the graphite was in the form of spheroids. In view of the unsatisfactory structure, annealing experiments and mechanical tests were not made on this material.

Machining Tests

A number of machining tests was made on small production batches of annealed ductile iron castings.

TABLE XII.—THE EFFECT OF MINOR ELEMENTS ON THE MECHANICAL PROPERTIES OF ANNEALED DUCTILE CAST IRON

Carbon %	2·86	2·98	3·06	2·80
Silicon %	2·23	2·13	2·20	2·18
Nickel %	1·06	1·04	1·00	0·94
Magnesium %	0·11	0·07	0·08	0·09
Tin %	0·09			
Lead %		0·02		
Antimony %			0·08	
Arsenic %				0·07
Yield Stress—tons/sq. in.	23·6	16·4	14·4	21·4
Ultimate Tensile Stress—tons/sq. in.	31·7	18·1	16·2	27·9
Elongation %	10	2	3	18
Reduction of Area %				19
Izod Impact—ft. lb.	6	3	4	14
Brinell Hardness (H/10/3000)	190	149	137	145

The patterns selected enabled a direct comparison to be made with blackheart malleable cast iron, and the operations included turning, facing, milling and drilling. Without going into details, it will suffice to put on record that machining times for annealed ductile cast iron were, in all instances, less than those for the corresponding operations on blackheart malleable cast iron. The improvements gave a reduction in machining time of

TABLE XIII.—THE EFFECT OF VARIATION IN ALUMINIUM CONTENT ON THE MECHANICAL PROPERTIES OF ANNEALED DUCTILE CAST IRON

Aluminium %	less 0·01	0·10	0·19
Carbon %	2·86	2·90	2·86
Silicon %	2·00	1·94	1·95
Manganese %	0·09		
Phosphorus %	0·02		
Nickel %	1·34	1·28	1·16
Chromium %	0·04		
Magnesium %	0·07	0·09	0·07
Photomicrograph	Fig. 5		Fig. 6
Yield Stress—tons/sq. in.	21·1	22·1	20·9
Ultimate Tensile Stress—tons/sq. in.	28·0	28·5	27·8
Elongation %	23·0	22·5	22·0
Izod Impact—ft. lb.	18	18	16
Brinell Hardness (H/10/3000)	146	143/146	143/146

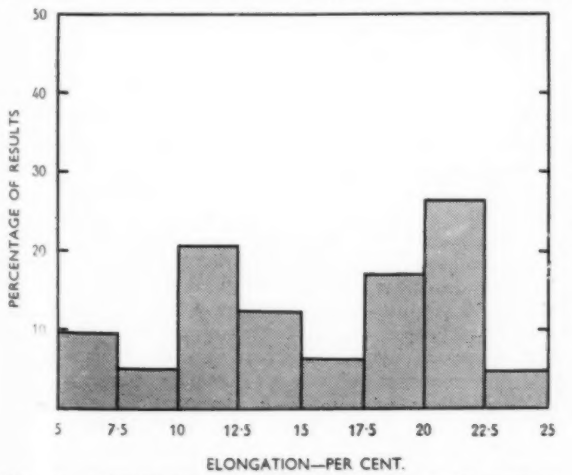

Fig. 10.—Distribution of elongation results on 91 casts of cupola-melted annealed ductile cast iron.

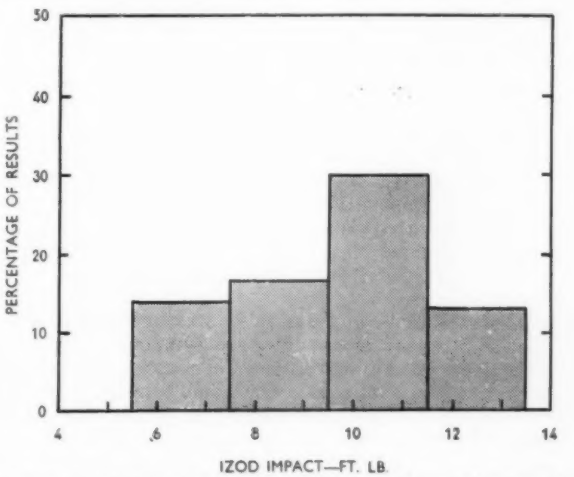

Fig. 11.—Distribution of Izod impact results on 91 casts of cupola-melted annealed ductile cast iron.

Fig. 12.—A $\frac{5}{8} \times \frac{1}{4} \times 8$ in. machined strip of annealed ductile cast iron bent cold by hammering.

20–40%: moreover, the finish was excellent and tool life was good. A group of typical castings is shown in Fig. 7.

Consideration of Mechanical Properties

All these castings were made from iron melted in the basic cupola from charges which consisted mainly of steel scrap, or foundry returns from such charges. The results of mechanical tests so far recorded have been obtained from test bars cast under laboratory conditions. Some readers may feel that similar results referring to test specimens produced under foundry conditions should be included. To meet this omission we furnish in Figs. 8–11 the results obtained from 91 separate casts of cupola-melted ductile cast iron, in the annealed condition. A cold bend test obtained from similar material is illustrated in Fig. 12; perhaps this test on a machined strip $\frac{5}{8}$ in. $\times \frac{1}{4}$ in. $\times$ 8 in. brings home more forcibly the excellent ductility and toughness of this high-impact annealed ductile cast iron.

Conclusions

The reader will have gathered that the subject of foundry costs has not been considered in this report, and it is not our intention to introduce it now. From the manufacturing point of view, however, the employment of basic cupola melting, and steel scrap as the major raw material, proved economical and satisfactory in providing a suitable base iron for magnesium treatment. The foundry problems involved are not inconsiderable and a very high standard of control and casting practice is essential.

The most striking characteristics of annealed ductile cast iron are its toughness, the ease with which it can be machined, and the excellent finish of the machined surface.

Acknowledgments

The authors wish to thank the Development and Research Department of The Mond Nickel Co., Ltd. for suggestions made and help given during the preliminary stages of this work; with this acknowledgment they would like to couple the name of Mr. W. W. Braidwood. They also wish to thank the Directors of Leyland Motors Ltd. and West Yorkshire Foundries, Ltd. for permission to publish this summary of the work, and Mr. Walter West for his help and encouragement.

Midlands Symposium on Analytical Chemistry

FOLLOWING the International Congress on Analytical Chemistry to be held at Oxford in September, 1952, the Midlands Society for Analytical Chemistry is arranging in Birmingham, a Symposium on Analytical Chemistry on September 11th and 12th, the main purpose of which is to give those chemists in the Midlands, who are unable to attend the Oxford Congress, the opportunity of hearing papers by, and meeting, analytical chemists of international repute.

The following chemists have expressed their willingness to attend and read papers:—

R. BELCHER (Birmingham), F. BURRIEL-MARTI (Madrid), G. CHARLOT (Paris), J. GILLIS (Ghent), J. HEYROVSKY (Prague), F. A. JOHNSON (Illinois), R. L. MITCHELL (Macaulay Institute), J. E. B. RANDLES (Birmingham), J. W. ROBINSON (Birmingham), T. B. SMITH (Sheffield), J. UNTERZAUCHER (Leverkusen), P. WEST (Louisiana), T. S. WEST (Birmingham), J. R. WINTERTON (Coventry).

PROF. FRITZ FEIGL (Rio de Janiero) has agreed to act as honorary chairman of the Symposium.

Meetings will be held in the Chemistry Dept. of the University of Birmingham and will commence at 10 a.m. The first day's programme will consist mainly of papers concerned with fundamental concepts of analytical chemistry and the second day will be devoted to original methods. Additionally, visitors will have the opportunity of seeing some of the research projects being carried out in the Research School of Analytical Chemistry at Birmingham which is one of the largest and best equipped in Europe.

The honorary secretary of the Society is W. T. Edwards, F.R.I.C., A.I.M., 100, Rymond Rd., Birmingham 8, who will be pleased to answer further enquiries. The registration fee for non-members of the Society is ten shillings, and for members five shillings, and as accommodation is limited, those wishing to attend should notify the Hon. Secretary as soon as possible, enclosing the appropriate fee.

Canadian Film Award

THE award for the best industrial by sponsored film in Canada, in 1951, has gone to "Packaged Power," a 32 minute, 16 mm. colour sound film, produced by Crawley Films Limited of Ottawa for Aluminium Limited, Montreal. The award was made by the Canadian Film Awards Committee. The film, by means of photography and animated cartoon, shows briefly, the process from bauxite to ingot and semi-fabricated products. It shows Aluminium Limited's existing bauxite operations in British Guiana, and its power and reduction facilities in the Saguenay Valley in Northern Quebec. The climax of the film concerns the new projects for mining bauxite and producing alumina in Jamaica, and the immense new hydro-electric project and smelter in Northern British Columbia. Copies of the film will shortly be available on loan from The Film Lending Library, Aluminium Laboratories Limited, Banbury, Oxon.

The Influence of Copper, Nickel and Tin on the Hot Working Properties of Mild Steel

By G. G. Foster, B.Sc., A.R.T.C., A.R.I.C., A.I.M., and J. K. Gilchrist, B.Sc., A.R.T.C., A.I.M.

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An assessment of the hot-working properties of mild steel containing various amounts of copper, nickel and tin has been made on the basis of bend tests carried out at high temperatures. The addition of nickel to copper-bearing steels results in improved hot-working properties, while the addition of tin to copper or copper-nickel steels has the reverse effect.

THE steady increase, in recent years, in the amounts of residual elements present in mild steel has become so marked as to necessitate, in many cases, a re-examination of the effects of these elements on the hot-working properties of the materials concerned. The present investigation is concerned with the occurrence of surface fissuring in mild steel, a phenomenon frequently associated with the presence of residual elements, notably copper and tin. It should be noted that throughout this paper the term "hot-shortness" is used to indicate the surface fissuring developed during slow deformation. The inherent brittleness occasioned by much higher copper or tin contents is not considered.

While it is known that hot-shortness of the type under discussion can be produced by the addition of copper or tin to mild steel, existing literature on the subject is scanty and frequently contradictory. An investigation into the influence of copper and of tin on the hot-working properties of mild steel was therefore undertaken; this investigation was later extended to include the effect of nickel additions.

Previous Work

Although a number of articles on this subject has been published, the value of much of the early work[1] is mitigated by the rough qualitative nature of the tests employed, and by lack of accurate data on the materials and test conditions utilised. The results of these investigations reveal wide discrepancies due, in part at least, to differences in the methods of testing and in the furnace atmospheres employed. It is also feasible that the distinction between the surface fissuring apparent on slow rates of deformation and the inherent hot-shortness of copper- and tin-bearing steels was not fully appreciated. Thus Lipin[2] maintains that 3% copper did not produce red-shortness while Ruhfus[3] and certain later workers limit this element to 0·25–0·50%. The influence of temperature does not appear to have been appreciated by early workers and the first mention of temperature effects appears to be that due to E. A. and L. T. Richardson.[4] They state that copper produces brittleness over a certain temperature range and that this range increases with increase of copper content.

In the main, the method of test employed till then consisted of heating a test-piece and subsequently hammering it on an anvil. This test-piece was then examined for surface defects. Variations of this technique were employed by Ellis[5] who measured the reduction in height of steel samples after striking them with a single blow of a hammer. Lorig and McLaren[6] on the other hand upset small steel cylinders to a standard amount and then examined microscopically for degree of surface cracking. In this way an investigation furnishing semi-quantitative data was possible and this contribution to the literature forms one of the main sources of information on the subject. A different type of test has been described by Eberle.[7] This test consists essentially of driving an oversized steel ball through a hole in a heated test plate and examining the cracking so produced.

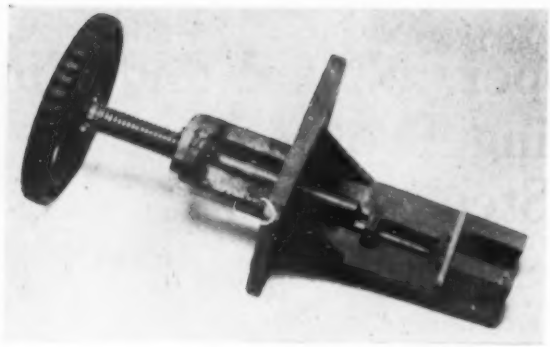
The only experiments of a quantitative nature so far reported have been those of Ihrig,[8,9] who carried out hot torsion tests on $\frac{5}{8}$ in. dia. specimens of a wide range of steels and determined the number of turns required to cause fracture. This test could be correlated with behaviour in the tube mill and was intended particularly for that application. No information has been given on possible correlation with other forms of hot working, in particular where deformation rates are much slower.

The main conclusions reached from previous investigations may be summarised as follows:—

(*a*) Studies of the scaling characteristics of copper-bearing steels[10] have shown that, owing to preferential oxidation of iron, copper is concentrated in the inner scale layer, leading to the formation of a copper-rich metallic phase[11] at the steel surfaces; penetration of this phase into the steel has also been observed.[6,12] Similar effects are to be expected in tin-bearing steels.

(*b*) Penetration of this metallic phase into the steel occurs during hot-working and gives rise to surface fissures. Information as to the copper and tin contents required to cause this type of hot-shortness is conflicting, and in the case of tin few accurate data are available.

(*c*) Since the occurrence of this surface cracking appeared to be limited to temperatures above the melting-point of the copper-rich phase formed at the surface, it was foreseen that it might be possible to minimise or eliminate the trouble by adding nickel to the steel. In this way, since nickel is also less readily oxidised than iron, the melting-point of the copper-rich phase would be raised by alloying with nickel. Some investigators[6,13] achieved considerable success in this direction although negative results have been reported elsewhere.[14] In the latter case, heating of the specimens was carried out in a furnace atmosphere containing sulphur compounds.



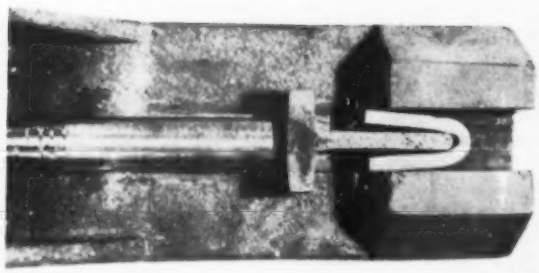


Fig. 1 (top).—Hot bend test apparatus with specimen in position.

Fig. 2 (bottom).—Specimen at finish of bend.

(*d*) Only one reference[6] to the effect of adding tin to a copper-bearing steel was found; in this case forging difficulties were encountered at temperatures lower than those associated with tin-free steels.

Present Methods of Test

On consideration of the problem, it appeared unlikely that a test could be devised which would be applicable to all forms of hot-working met with in practice. Attention was therefore concentrated on devising a procedure which would have as wide a field of application as possible, while permitting of ready standardisation and, so far as practicable, of quantitative evaluation. A relatively small test piece size was considered to be advantageous, as the likelihood of dealing with material from service failures and from the works was envisaged. Such material might not always be ample for large sized specimens. The form of test finally adopted represented the best practicable compromise between the various factors involved.

Since the results were to be correlated with behaviour during hot-working operations such as pipe bending and forging of various boiler parts, all involving bending at comparatively low rates of deformation, it was decided to adopt a simple 180° hot-bend test. A quantitative measure was obtained by determining microscopically the average depth of penetration of cracks.

Although a hot-torsion test of the type developed by Ihrig would have given a quantitative measurement more directly, it was felt that difficulties in correlating a rapid torsion test with bending operations of the type described would outweigh any advantages. The large size of specimen required was also detrimental.

To eliminate sources of error as far as possible, it was advisable to conduct the bend tests at a constant temperature instead of the usual procedure of bending the specimen as it cooled after withdrawal from the heating furnace. Consequently an apparatus was constructed to permit of bend tests being carried out while the specimen was inside the furnace. This apparatus is illustrated in Figs. 1 and 2 and was designed to fit an electric muffle furnace, the main parts being cast in a nickel-chromium heat-resisting alloy. By this means the specimen could be bent 180° round a mandrel $\frac{1}{4}$ in. thick.

Experimental Procedure

Fifty 18 lb. heats of mild steel with varying additions of copper, nickel and tin were melted in a 35 kVA high-frequency furnace. Because of the nature of the iron base employed, it was not possible to reduce the copper and nickel contents of the finished steel below 0·06-0·08% and 0·03-0·06% respectively. Each heat was deoxidised with aluminium and subsequently cast into a single round ingot which was later forged to $\frac{3}{4}$ in. square bar. From this bar, test pieces 3 in. × $\frac{3}{8}$ in. × $\frac{1}{4}$ in. were machined and polished to 1G emery paper after slightly rounding the edges with a file.

Duplicate hot-bend tests were carried out on each steel at each of six temperatures (every 50° from 950° to 1,200° C.). The hot-bend apparatus was first heated up in the furnace to the test temperature, after which a specimen was placed in position. Normally, 5 to 10 minutes were required for the specimen to attain the furnace temperature, after which 15 minutes soaking time was allowed before bending the specimen by rotating the handwheel. Experiments with soaking times of up to 3 hours indicated that an increase of that order had no significant effect. On completion of the test, the apparatus was momentarily withdrawn from the furnace in order to remove the specimen and insert a fresh test piece.

In addition to specimens from these experimental steels, similar tests were conducted on 32 commercial steels, in the form of pipes, forgings, etc., which had revealed surface fissuring during fabrication.

Examination of Test Pieces

From the twelve bent test pieces of each steel, a representative set of six, one from each temperature, was photographed. A few typical examples are reproduced in Fig. 3. For comparison with the results of the microscopic examination, the visual appearance of the specimens was recorded on the following arbitrary scale:—

0	— no fissures visible	○
1	— slight fissuring	△
2	— severe fissuring	▽
3	— specimen broken	□

The results so obtained are shown graphically in Fig. 4 which also contains, for comparison, the results from examinations conducted on the commercial steels. For convenience in presentation of results, the steels have been divided into three groups according to nickel content, these groups having nickel contents of approximately zero, equal to the copper content and double the copper content, respectively, and the commercial steel is indicated by a solid symbol. The

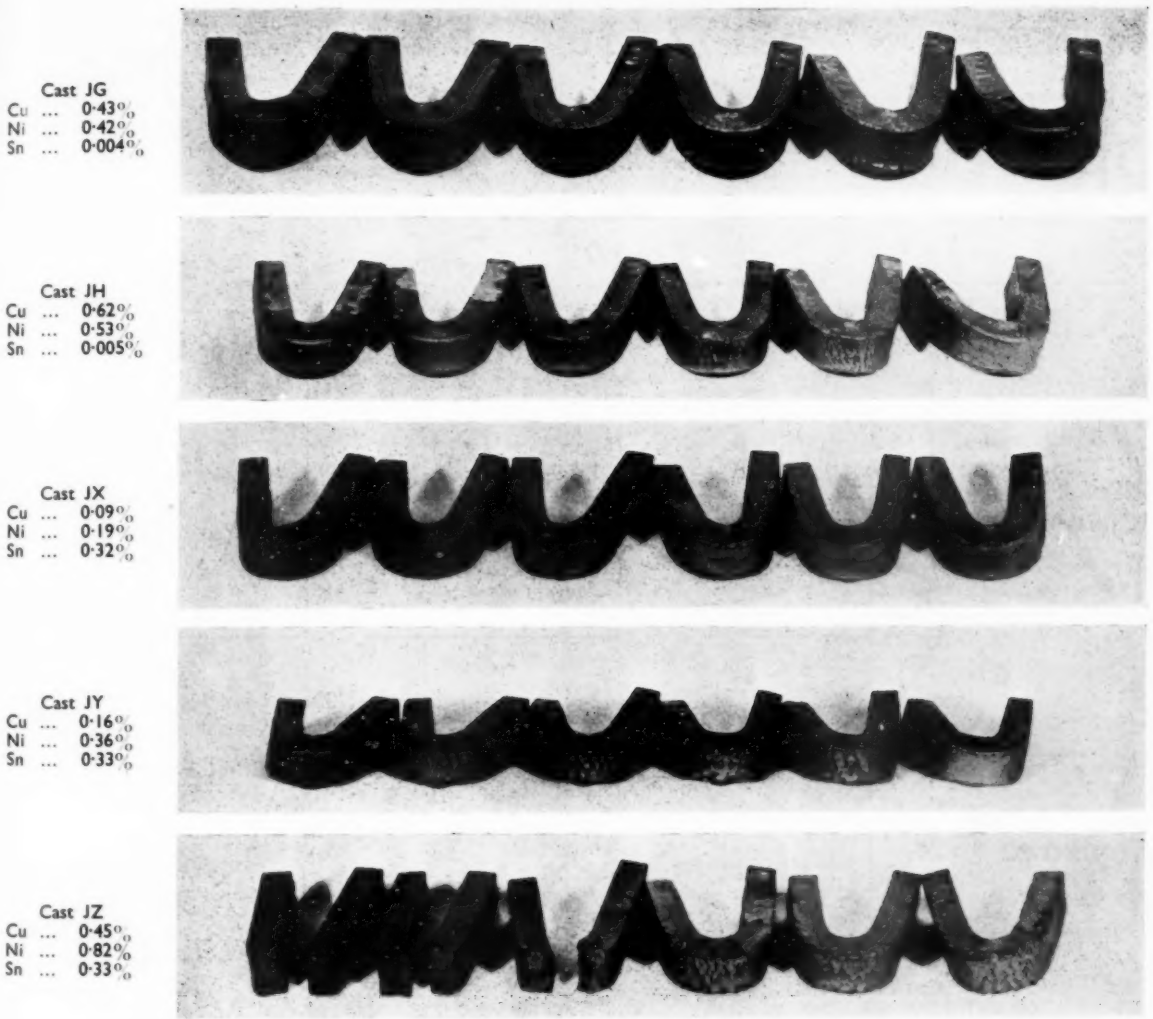


Fig. 3.—Typical examples of hot bends. The temperatures of bending in each set of tests were (left to right) 950° C., 1,000° C., 1,050° C., 1,100° C., 1,150° C. and 1,200° C.

curve drawn on each graph indicates approximately a rating of 1½ on the arbitrary scale, this being employed as the dividing line between satisfactory and unsatisfactory specimens.

Each test piece from the experimental steels was subsequently sectioned longitudinally for microscopic examination. These sections normally contained a number of fissures penetrating inwards from the outer surface of the bend. Using a magnification of 50 diameters, the depth of each fissure was measured and the average fissure depth per specimen calculated. The results obtained are shown graphically in Fig. 5.

Discussion of Results

(a) *Visual Examination*

The following features are evident in the results given in Fig. 4 :—

Copper Steels : In the absence of nickel and tin, fissuring did not occur to any significant extent below 1,050° C. From this temperature upwards, surface fissuring became evident in steels of the higher copper contents, the limiting percentage of copper being reduced slightly as the test temperature rose.

Tin Steels : At the minimum copper content attainable (0·06–0·08%), the addition of up to 0·5% tin caused no serious fissuring. Very bad results were obtained, however, with a 0·99% tin steel containing 0·17% each of copper and of nickel.

Copper-Tin Steels : The addition of tin to copper-bearing steels led to a marked deterioration in hot bend test results at all temperatures.

Copper-Nickel Steels : It will be seen that nickel additions have had the effect of reducing the degree of hot-shortness. In particular, while tin-free copper-bearing steels of low nickel content were free from hot-shortness at temperatures up to 1,000° C., similar steels with a Ni : Cu ratio of 1 : 1 were satisfactory up to 1,050° C. and those with a Ni : Cu ratio of 2 : 1 up to at least 1,200° C. These results were valid up to the

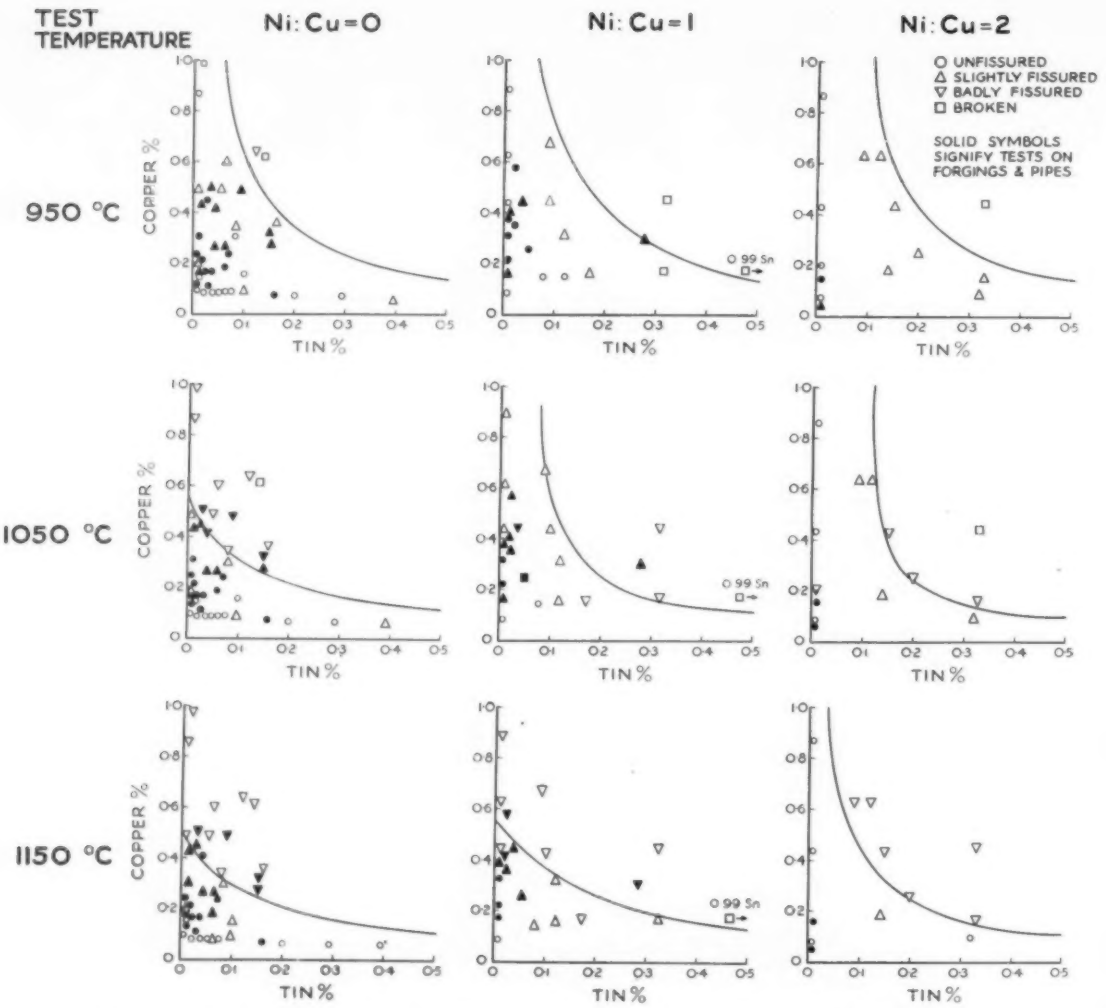


Fig. 4.—Graphs representing the visual appearance of the specimens after hot bending.

maximum copper contents investigated (approximately 0·9%).

Copper-Nickel-Tin Steels: The addition of tin rapidly reduced the effectiveness of nickel in combating surface-fissuring. For tin contents of 0·1% or more, nickel appeared to be completely ineffective.

(*b*) *Microscopic Examination*

On considering the results for average fissure depth per specimen, similar effects are evident to those just described. The scattered results of the plot of fissure depth against copper content in those steels containing 0·1% and 0·3% tin indicate that nickel additions do not appear to improve the susceptibility to surface fissuring in copper-bearing steels containing as little as 0·1% tin.

Statistical Examination of Results

The general effects produced by the three elements were confirmed statistically by calculating the correlation coefficients (par ial) between the average fissure depth and the copper, nickel and tin contents of the steel. The coefficients were found not to vary significantly with testing temperature owing to the high standard deviation associated with a relatively small sample of this nature. The following average results are therefore representative over the temperature range investigated :—

Partial correlation between copper content and average fissure depth	+0·65
Partial correlation between nickel content and average fissure depth	−0·39
Partial correlation between tin content and average fissure depth	+0·54

These results, which are based on 50 pairs of observations, are all significant. It thus follows that while high copper and tin contents are associated with increased fissure depths, additions of nickel are associated with lower fissure depths.

Conclusions

The significant features revealed by this investigation are in agreement with the accepted theory of the mechanism of surface fissuring during hot-working. This theory postulates the formation of a copper-rich phase at

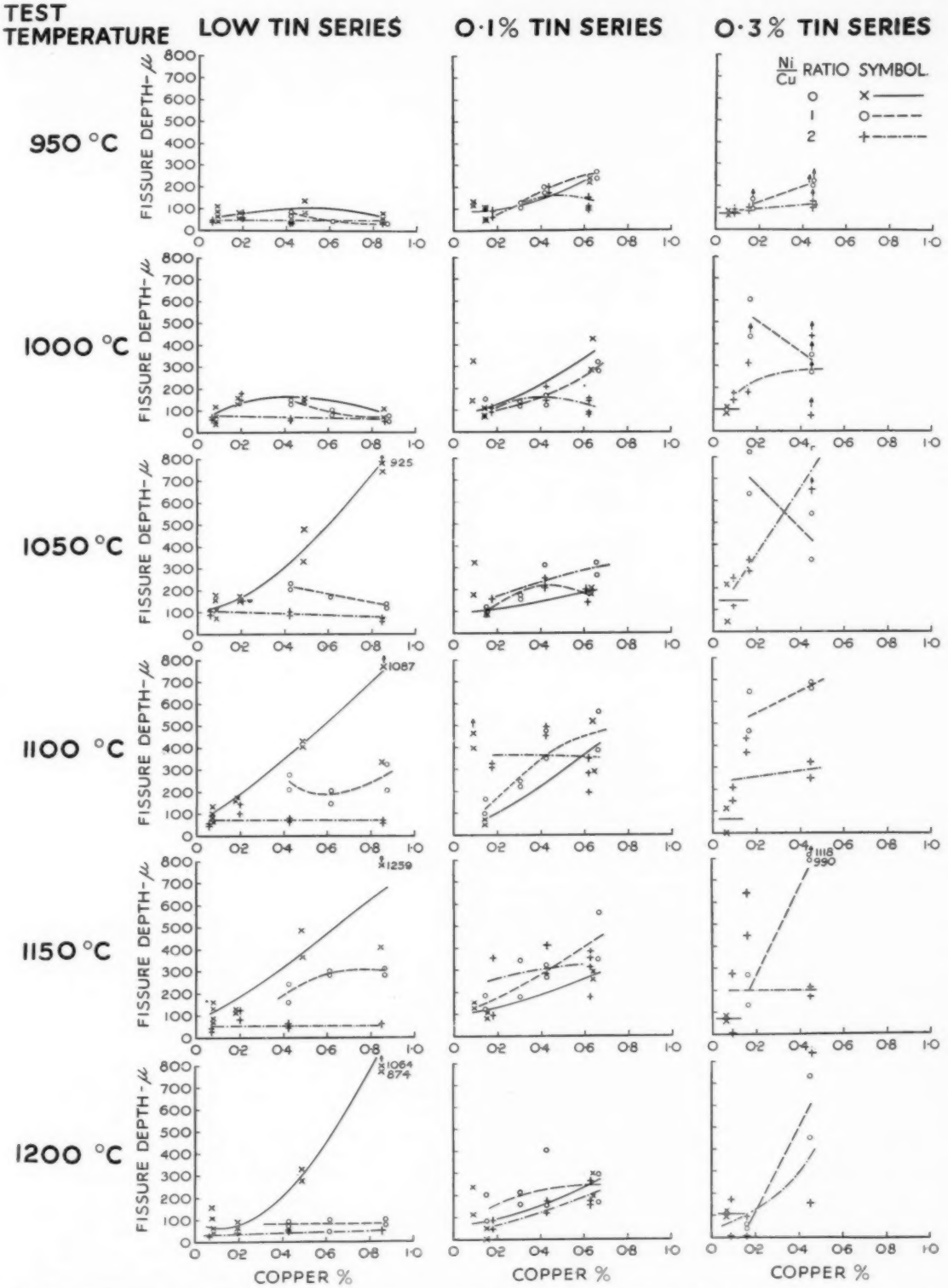


Fig. 5.—Graphs showing the depth of fissuring resulting from bending the steels at various temperatures.

the surface of the steel by selective oxidation and subsequent penetration of the alloy during working. Consequently the rate of oxidation is an important contributory cause of failure, and hence those factors influencing the oxidation rate are of critical importance. One of these factors is, of course, temperature, but from the results obtained, it appears that penetration occurs only at temperatures above the melting point of the copper-rich phase, although the temperature range investigated was insufficient to establish this point definitely for those steels containing considerable amounts of tin. Further work on related problems has indicated the possibility of copper penetration taking place at much lower temperatures, but in this case it is probable that very much longer heating times would be involved; little information is yet available on the conditions under which it may occur.

On the basis of the above theory, the detailed results of the investigation may be summarised as follows :—

(1) Copper, in the absence of nickel and tin, led to hot-shortness in hot bend tests when present in amounts greater than approximately 0·5% and at temperatures above 1,000° C. At and below this temperature no hot-shortness was evident up to at least 1·0% copper. This transition temperature presumably represents the melting point of a copper-rich phase containing other elements in solution.

(2) The addition of nickel to copper-bearing steels progressively raised this transition temperature until, for a nickel content equal to double the copper content, no hot-shortness was found within the temperature range investigated for copper contents up to at least 0·9%. This is in accordance with the known effect of nickel in raising the melting-point of copper-rich alloys.

(3) The addition of tin to copper or copper-nickel steels led to hot-shortness at progressively lower copper contents at all the temperatures investigated. In the presence of tin, nickel became ineffective in combating hot-shortness. These features would agree with the formation of a copper-tin phase of comparatively low melting point.

(4) In a few cases, hot-shortness at temperatures around 1,000° C. was found in steels which behaved satisfactorily at all other temperatures within the normal testing range. This phenomenon has also been found occasionally when examining failures of commercial steel and is apparently due to some factor not yet investigated. The data available rule out the question of sulphur contamination. Further work on this problem is envisaged.

(5) The results of this investigation are applicable primarily to hot-working processes involving bending. They are probably not applicable in their entirety to processes such as rolling and tube piercing where deformation is more rapid and of a different character. The hot torsion test developed by Ihrig[8] would doubtless be more suitable in these cases.

(6) All tests for this investigation were conducted in an air atmosphere. When using furnace atmospheres containing sulphur, marked deterioration of hot-working properties can be expected, due to the formation of sulphides in the scale. These sulphides form low-melting point eutectics which then penetrate into the steel base, as discussed by Dickie[14] and Smith.[15] In this case nickel may have an injurious instead of a beneficial effect, owing to the low melting-point of nickel sulphide.

Acknowledgments

The Authors are indebted to the Directors of Messrs Babcock & Wilcox, Ltd., for permission to publish this work and, in particular, to Mr. C. H. Davy, Works Director and Mr. W. G. Marskell, Superintendent of Research Department, for their interest and encouragement during the investigation.

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Correspondence

The Editor, METALLURGIA.

Dear Sir,

I should be obliged if you would allow me to make an acknowledgment which was ungratefully omitted from my article on "Immersion Pyrometry in the Steel Industry" in your February issue. Photographs there reproduced showing immersion pyrometers of the trolley, hand-manipulated and permanently attached types were all reproduced by the kind permission of Messrs. Steel, Peech and Tozer (branch of The United Steel Companies, Ltd.).

Yours faithfully,

FRANCES MORTIMER.

The British Iron and Steel Research Association,
London, W.1. 24th April, 1952.

New Extension for F. J. Edwards

F. J. EDWARDS, LTD. will shortly open new premises in Park Street, Islington. This extension has been necessitated by the increased demand for their products, both home and overseas.

In the past, stocks have been housed in depots scattered over a wide area in London with the attendant difficulties of buyers having to visit different depots, in some cases miles apart. The new warehouse, which covers an area of more than 100,000 sq. ft., will enable all stocks to be gathered under one roof, centrally situated, with amenities for buyers to inspect machinery, both new and reconditioned, under the best possible conditions.

A noteworthy feature of this project is the fact that it has been carried through in its entirety, from a derelict bomb site to this magnificent new structure, by the Company's own building maintenance staff and labour force. The necessary licences were granted only on this condition.

Heat Treatment Plant Developments

Recent Installations for Ferrous and Non-Ferrous Metals

In view of the need to reduce alloy additions of critical elements to a minimum, and because of the stringent demands on ferrous and non-ferrous components, restrictions have been imposed on the liberties that can be taken in obtaining the desired properties. To assist the engineering industry to make the best use of these materials, further developments have been made in heat-treatment equipment, the main objects being to simplify operations, maintain uniform temperatures and economise in the use of the heating medium employed. Some of the developments in furnace design are reviewed here.

HEAT-TREATMENT furnaces are used in almost every phase of manufacture that involves the use of ferrous and non-ferrous metals, from the ingot stage through the various operations to the finished product. The temperatures required vary considerably, according to the material or component and the purposes for which it is to be used, and may be as low as 200° C. through a range extending to about 1,330° C. Different types of heating media are used, which include solid fuel, oil, gas and electric power, and in designing suitable furnaces the furnace engineer is primarily concerned with the efficient use of the heat developed and simplicity in operation for the purposes desired. The best results are usually obtained in furnaces designed for a special purpose, but, as a rule, furnaces must be designed to enable a range of work to be treated (although in many cases it is a limited range) and general purpose heat-treatment furnaces have also reached a relatively high stage of efficiency.

Under present conditions, in which many alloys are in short supply, involving modifications in compositions normally used, the need is greater for heat treatment of both ferrous and non-ferrous metals to be carried out under rigid, accurate and reproducible conditions. In addition to heating the materials or components being treated, facilities are usually necessary to charge and discharge the furnace whatever type it may be, and many mechanical devices have been developed to ensure ease of working.

Fully automatic temperature control is now regarded as standard practice. This is achieved by thermocouples suitably placed in the heating chamber and connected to indicating or recording control instruments. There is an increasing use of special atmospheres in furnaces, either to eliminate or reduce scaling of work during treatment.

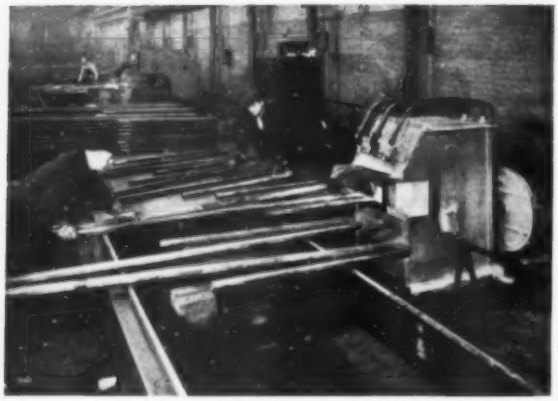
There are many factors which must be taken into consideration in the design and operation of heat-treatment furnaces, and the value of the result desired has an important influence in determining the type. The cost of the heating medium employed, temperature and atmosphere control, and other phases in heat-treatment operations are really incidental to the main consideration, which involves the quality of the treated product or component and its overall cost. In making a choice of heat-treatment equipment, therefore, it is necessary to keep in mind the need for producing a high-grade product at low cost, using that form of heating medium and that type of equipment which will give the results under the conditions that operate in the particular works at which the installation is contemplated. The furnace must give satisfactory service concerning the degree of uniformity of heating, consistent with possible variations of output and conditions imposed by the shop requirements. For those products that are to be heated for treatment in their final stages of manufacture, there is a standard of accuracy of temperature and uniformity, a degree of reliability and control, that may not be attainable except with the most refined and elaborate methods. In such cases the actual cost of heat units used in the furnace is secondary to the essential need of attaining the required standard of quality of the product, since the cost of failure to satisfy this standard consistently far outweighs the small increment in cost in the actual energy applied and the capital charges involved in the provision of more elaborate equipment.

Furnace Types

Heat-treatment operations are usually carried out in batch, semi-continuous, or continuously operating furnaces. The batch method, with or without movable batch container, was developed first, although apart from the box-type heating chamber, there is no real comparison between modern batch-type furnaces and the early designs. These furnaces are very popular because of their adaptability to many products varying widely in size, quantity, and even type of treatment. When the output of a product requiring the same heat treatment is fairly constant, an opportunity is provided for using some type of furnace in which the material or components to be treated can be handled automatically, involving continuous heating and cooling operations. Between these two types there are various designs which can be regarded as of a semi-continuous character. Many continuous furnaces have their heating chamber divided into zones and are provided with time-cycle control with the object of repeating accurately a desired treatment with a view to obtaining uniform products. In the following notes some examples of recent installations are given from which it will be noted that heat-treatment furnace design and construction is a specialised industry.

Reheating Furnaces

There is a very wide range of furnaces designed for heating billets or slabs preparatory to hot rolling or extrusion. These are usually of the semi-continuous type, and while they can be operated on a time-cycle, it must be arranged to conform with the requirements of the rolling mill, forging or extrusion press. In some cases, however, efforts have been made to speed up the heating time by means of a specially designed furnace. An interesting example of this type is a tube heating furnace recently designed and built by The Dowson and



Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 1.—Tube heating furnace which, by concentrating combustion in a confined space, has reduced the heating time for tube bending from 7 to 1½ minutes.

Mason Gas Plant Co., Ltd. which, by concentrating combustion in a confined space, reduced the heating time for superheater tube bending operations from 7 min., in an othodox furnace to heat a 2½ in. outside diameter tube, to 1½ min.

This furnace, which is shown in Fig. 1, uses town's gas through two Min-O-Max automatic proportioning burners firing directly into the furnace chamber. The chamber is so shaped that the combustion products follow a path similar to a figure 6 before exhausting through the charging opening, and because of the very high temperature developed the majority of the inner lining of the chamber is of Sillimanite, with adequate insulation to prevent radiation from the furnace structure. A cleaning door and frame is provided for scale removal and the casing is tapered back at each side to accommodate the second hairpin bend of the superheater tube.

Each furnace is a complete unit and is fitted with an electrically driven blowing fan delivering air at 28 in. w.g. to the burners, while the gas is governed to zero pressure before being induced in correct proportion to the air flow. Some indication of the successful operation of these furnaces is shown by repeat orders in this country as well as the number of units being constructed for export to Australia, South Africa and Belgium.

It is now well known that in the lower heating range, up to about 600° C., very little heat is transferred by radiation but much use is made of forced convection, by means of circulating fans, to increase the speed of heat transfer to the charge and so shorten the heating time. This system has been adopted successfully in the large oil-fired aluminium billet heating furnace designed and built by the Dowson and Mason Gas Plant Co., Ltd. and illustrated in Fig. 2.

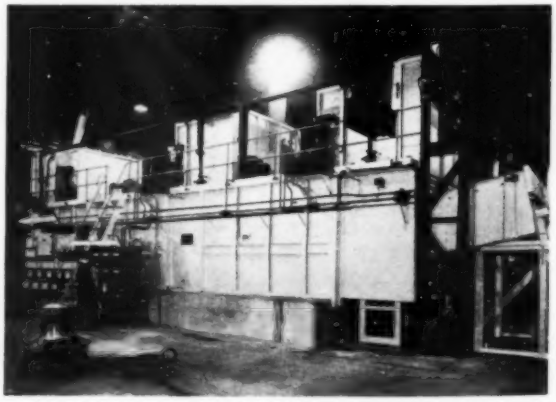
The heating chamber of this furnace has a length of 48 ft. 6 in. and a width of 7 ft. 6 in. and the inner walls of the furnace are in the form of a box muffle. Six roller-type chains, with nickel-chrome pins, convey the aluminium billets, each weighing about 400 lb., through the furnace to the rolls, and outputs of 4 tons/hr. of aluminium alloy or 5–6 tons/hr. of commercially pure aluminium can be handled through this furnace.

Three combustion chambers, each with hot-gas circulating fans mounted on top of the furnace, are heated by automatic proportioning oil burners. The circulation of hot gases is damper controlled, allowing adjustment to any part of the furnace and, after passing over the billets, the gases flow to the ends of the furnace through return ducts in the roof so that maximum recirculation of hot gases is achieved. For temperature control, the furnace is divided into three zones, each being fitted with fully floating temperature control equipment and hydraulically operated regulators acting on the air supply to the burners. Adequate safety controls are fitted to prevent overheating of the fans or damage to the furnace by failure of combustion air or oil. It is claimed that a very high degree of temperature uniformity and flexibility of operation is obtained from this furnace.

Considerable attention has been given to the use of low-frequency induction heating, particularly in the United States. In order to investigate and study the claims of this form of heating Mr. J. McDonald of McDonald Furnaces, Ltd., visited the United States, and as a result this firm has designed a plant in which is introduced a new feature in temperature control and considerable interest is being shown in this development.

It is noteworthy that this method of heating billets, in preference to the normal conveyor or pusher-type electric furnace, is becoming increasingly popular in the United States and is being developed in this country. The advantages obtained by low or normal frequency induction heating of billets above 3 in. diameter cannot be ignored, and it is evident from investigation of plants in operation and the reaction of industrial users, that a move from present accepted design of billet heating furnaces is likely in this country in the near future.

The low-frequency induction heater will operate on any standard 3-phase 50-cycle supply and can be put into commission in a few minutes. The main advantage is the fast rate of penetration, and by carefully designing the coil the uniform rate of axial heat development in the billets is assured. A contact thermocouple arranged to maintain a consistent pressure on each billet indicates on the instrument the actual charge temperature. Operating in the orthodox manner, the power is controlled by a contactor. In contrast to the American method of working, in a number of factories in this country extrusion is regarded as "jobbing work"



Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

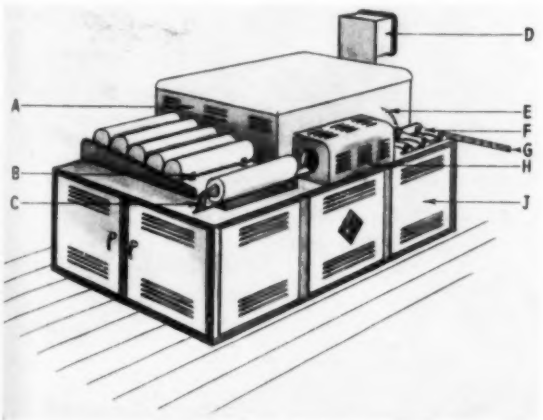
Fig. 2.—A large oil-fired aluminium billet heating furnace with outputs of 4 tons/hr. of aluminium alloy billets, or 5–6 tons/hr. of commercially pure aluminium billets.

where numerous stoppages can be expected. To obviate switching off the plant or returning ejected billets to the charge end, McDonald Furnaces, Ltd. have patented a device for the automatic holding of the billet at the controlled temperature within the permissible temperature differential, dispensing with the use of an automatic timer.

Provided the ramp is constantly supplied with billets, the press operator can control the heating and delivery of billets to the extrusion press without leaving the press controls. Additional coils for varying diameter of billets are supplied to cover the required range and can be changed within approximately 15 minutes. In operation the plant, a line drawing of which is shown in Fig. 3, is cool, all heat losses being carried away by cooling water. In comparison with furnaces normally designed for this purpose, the space occupied by the complete plant is very small. The units comprise tap-changing transformer, condenser for power factor correction, and oil circuit breaker for direct connection to the mains supply.

Much progress has been made in the supply of high frequency induction heating equipment, and recently a range of standard machines has been developed by Birlec, Ltd., for the black bolt industry for the purpose of heating bolt pins prior to heading. The heater, shown in Fig. 4, is a compact unit occupying a floor space of only 4 ft. by 3 ft. It can easily be located next to its associated press as it is completely free from radiated fumes or heat.

The bolt pins are loaded into a magazine at the open top of the machine; they fall, one by one, through slots into jaws which grip and move them into the H.F. induction heating coils, of which there are six to each machine, and the heated pins are delivered, in rotation, down a chute to the press operator. The labour requirements of the bolt heater are very small as one man can



Courtesy of McDonald Furnaces, Ltd.

A. Enclosure Housing Transformer.
B. Toggle Gear Retaining Billets.
C. Pneumatically Operated Pusher.
D. Indicating Temperature Controller.
E. Contact Couple on Swivel Arm.
F. Runout Gear Continuously Operated.
G. Idler Roller Track to Press with Mechanical Stop.
H. Removable Cover Over Coil.
J. Enclosure Housing Contactor and Mechanical Gear.

Fig. 3.—Line drawing showing the application of the low frequency induction method of billet heating.

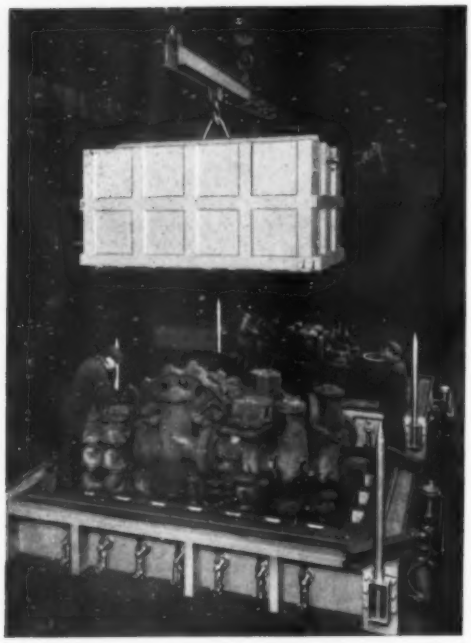
Courtesy of Birlec, Ltd.

Fig. 4.—High-frequency induction equipment for heating bolt pins prior to heading.

easily keep a battery of six or ten machines continually loaded. The maximum output of these machines, which are standardised from $\frac{1}{2}$ in. to $1\frac{1}{4}$ in. diameter stock, is 1,500 pins per hour, and not only are direct operating costs considerably reduced when compared with older methods, but subsequent tool costs are reduced by as much as 25%. The clean shop conditions facilitated by these machines also encourage the influx of labour to the industry, in which recruitment problems are becoming yearly more difficult.

Annealing Furnaces

Designs of annealing furnaces vary considerably and depend largely on the type of work for which they are intended and on the material to be treated. In many cases modifications have been made in the design of furnaces which have been previously described in this journal. In the May, 1951, issue, for instance, it was suggested that the orthodox air circulated batch furnaces for the "pack" annealing of aluminium sheets and circles made the process a rather long one, due to the limitation of the temperature "head" to prevent overheating on the outer edges, and also because the packs, even when spacers are employed, do not lend themselves to thorough air circulation. To allow these two limiting factors to be adjusted, in a measure, led to the comparatively recent development of the continuous flash annealing furnace for aluminium sheets and circles. Modifications have been made in several designs to ensure uniform heating so that the sheet under treatment is heated to its annealing temperature uniformly in the time required to give recrystallisation of the structure of the material, and elimination of rolling line, without allowing time for subsequent grain growth. It is recognised that great care is necessary in the design of the conveyor mechanism to prevent marking of the annealed sheets. One of these flash-annealing furnaces is dealing successfully with sheets up to 6 ft. in width. It is claimed that the operation of these furnaces has proved that continuous treatment of aluminium sheets offers a most versatile and economic method of producing them in the physical condition required.



Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 5.—A portable cover furnace for annealing steel castings; it has two bases and one cover.

Although considerable progress is being made in the development and installation of continuous annealing furnaces, batch furnaces for this process still predominate. This is particularly true for the annealing of steel castings for which the portable cover furnace has many advantages. Among the many design features of this type of furnace is the accessibility of the base and ease of charging and discharging components from it. This type facilitates maximum loading which increases the thermal efficiency of the furnace.

An attractive addition to the range of furnaces by Dowson and Mason Gas Plant Co., Ltd. is the portable cover furnace shown in Fig. 5. With two bases and one hood, having a working chamber 5 ft. 3 in. high and two bases each 9 ft. 9 in. long and 4 ft. 9 in. wide, semi-continuous operation can be achieved, with the warm hood being transferred to a loaded base after the cooling cycle has been completed in the other. It is being operated for the annealing of steel castings, but this type is suitable for a range of materials and products that need annealing.

The absence of doors, the sand-sealed lightweight refractory-lined hood, built-in air recuperators and extreme uniformity of temperature give high thermal efficiency, and the simplicity with which the gas burners can be lighted and adjusted, coupled with ease of general maintenance, are advantages which should be kept in mind when making a choice.

A more recent portable cover furnace design uses height rather than the more orthodox floor area dimension and thus overcomes one of the difficulties in many factories of finding floor space for new equipment. A furnace incorporating this feature is shown in Fig. 6; it has all the advantages of easy lighting, sand-sealed hood for gas-tightness resulting in temperature uniformity and low fuel consumption, and ease of handling materials to and from the base, which, in this design, is by means of a small 6 cwt. hand traversing, electrically operated lifting block on a swinging jib.

This furnace, which is fired with town's gas, has a hearth 4 ft. wide and 7 ft. 6 in. long, and the hood, when lowered, gives a height from hearth to underside of the flat roof of 3 ft. 8 in. Lightweight insulating refractories are used in the hood, which weighs less than 5 tons, and a hoisting speed of 20 ft./min. is given by the electrically-operated hoist mounted on the bridge structure of the furnace. The unit is complete with built-in contactor gear operated from a push button station in one vertical member of the bridge, while a micro-speed unit reduces the hoisting and lowering speed to 30 in./min. when the hood is near the base to avoid risk of damage when settling.

The furnace illustrated is designed to accommodate a load of 4 tons of castings and is suitable for temperatures up to a maximum of 1,050° C. It can be used for a diversity of operations such as preheating, stress-relieving, annealing of either ferrous or non-ferrous products, malleableising, etc. An air blowing fan and single point recording and controlling instrument form part of the installation, which is a worthy addition to the range of portable cover furnaces designed and built by The Dowson & Mason Gas Plant Co., Ltd.

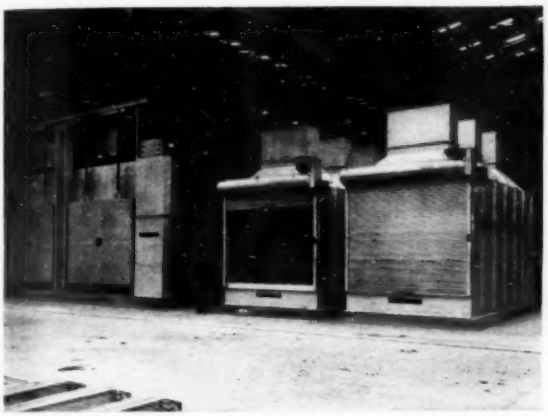
The large batch-type furnaces shown in Fig. 7 form part of a repeat order received by G.W.B. Electric Furnaces, Ltd., for annealing aluminium and aluminium alloy strip in coil form at temperatures up to 420° C. at the Falkirk Works of The British Aluminium Co., Ltd. Each chamber, which is 18 ft. long, 9 ft. wide and 7 ft. high, can hold a charge weighing up to 12 tons and is rated at 550kW, the heating elements being arranged

Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 6.—A portable cover furnace incorporating its own cover lifting equipment and swinging jib charging crane.

in three independently controlled zones. Forced air circulation is employed, provided by three centrifugal fans in each chamber. For lengthy soaking periods, the electrical loading can be reduced to approximately one-third by means of a star delta switch, thus affecting considerable economy in operation and preventing undue wear on the contactor gear. The two separate chambers on the right are for cooling the charge, and each can contain a 12-ton load from one of the furnace heating chambers. Cooling is effected by two large capacity fans giving an approximate temperature reduction of the heated coils from 420 to 30° C. in six hours.

An interesting example of a chain-conveyor furnace used for the annealing of aluminium foil on spools is illustrated in Fig. 8, which shows the loading end of a 350kW furnace built recently by the Electric Resistance Furnace Co., Ltd., for handling approximately 1 ton/hr. of foil, ranging in thickness from 0·017 to 0·025 mm., at the Silvertown Works of Venesta, Ltd.

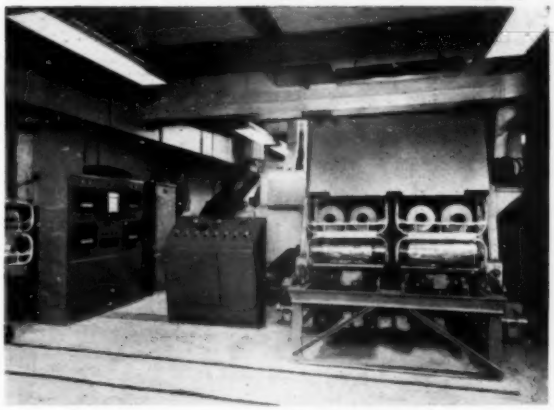


Courtesy of G.W.B. Electric Furnaces, Ltd.

Fig. 7.—Large batch type electric furnace for annealing aluminium and aluminium alloy strip in coil form.

This furnace, which comprises a heating chamber 29 ft. long and a cooling chamber 77 ft. long, with door openings 6 ft. 6 in. wide and 2 ft. 9 in. high, incorporates the Efco-Lindberg cyclone heater system. The heat is dissipated in four independently controlled air zones. For this purpose, four heaters are positioned along the side of the furnace, each comprising an easily removable heater bank, a centrifugal type fan, a thermostat and an air switch operated by a small fan carried on the main shaft to ensure that the heating elements and the fan are not independent. The heated air is blown via ducts, provided at the furnace roof in each zone, through deflector plates initially adjusted to ensure uniform air flow through the zone, and returns through the charge via similar ducts provided at the side of the furnace below the rollers. Four cooling fans provide cold air to the cooling chamber, shutters being arranged in the side walls and roof of the ducting to regulate the air as required. In this particular example the air exhausted from the cooling chamber is used for other purposes in the factory.

The furnace hearth is provided with recessed idle rollers carried on racks, the hearth itself being constructed of brick piers running the full width and designed to



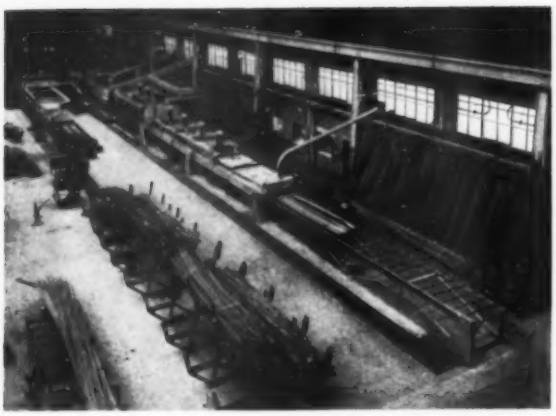
Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 8.—Charging end of electric furnace for annealing approximately 1 ton/hr. of aluminium foil on spools.

support the traverse members which, in turn, support and locate the racks and conveyor chains. Inlet and outlet tables are provided. There are four chain conveyors, two being high-speed units and the other two low-speed. One high-speed unit is for transferring the charge from the inlet roller table to a position inside the heating chamber; the other is for discharging from the end of the heating chamber to the cooling chamber. The two slow-speed units convey the charge through the heating and cooling chambers, respectively. The chains carry pawls which engage the tubular type charge carriers, the pitch of the pawls being so arranged that the carriers are conveyed, through the heating and cooling chambers, independently.

Operation of this furnace is automatic, since the movements of the inlet and outlet doors of the furnace chamber are synchronised with the high-speed chain conveyor; temperature control is effected by two thermocouples—one recording and one indicating—in each zone; and the timing device is set to give the desired time sequence. The only manual work required is to load the charged carriers on to the inlet rollers from a roller-topped table.

Gas-fired equipment continues to play an important part in Birlec heat treatment furnace production, and a large 42 in. width roller hearth furnace for clean annealing non-ferrous tubing is one recent example of many equipments put into service. Fig. 9 shows this unit on the right with one of the first Birlec gas-fired furnaces installed by its side. The heated length of this new furnace is 18 ft., the majority of its total length (135 ft.) consisting of the cooling chamber. The radiant heating tubes are arranged in three zones, each under automatic, independent temperature control. The gas demand is about 1,600 cub.ft./ton of work treated and an additional 450 cub.ft./hr. is required for protective atmosphere within the furnace. Three fans are installed in the heating chamber and six in the cooling chamber. The provision of fans in a furnace of this kind is a new development, enabling greater output from the same space occupied by the equipment. The normal output of this furnace is of the order of 30 cwt./hr. of brass tubes at 650° C.—the furnace normally operating at this temperature, although designed for temperatures up to 900° C. The protective gas for this furnace is obtained from a Birlec exothermic atmosphere generator



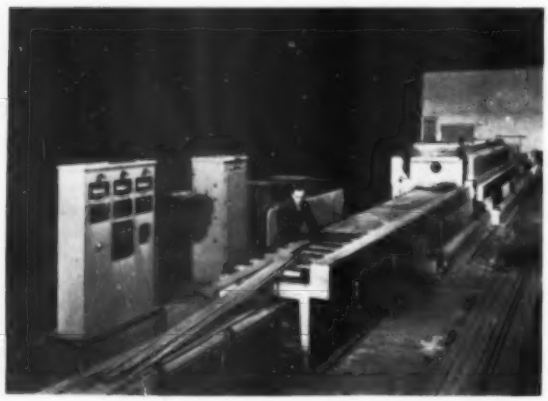
Courtesy of Birlec, Ltd.

Fig. 9.—Gas-fired roller hearth furnace for clean annealing non-ferrous tubing.

which is housed in a separate annex. This unit is rated at 3,000 cu.ft./hr. output and is equipped with double-stage sulphur purification equipment.

A roller hearth electric furnace, which is designed for an output of 1 ton/hr. of brass tubes annealed at temperatures ranging between 250° and 650° C., is shown in Fig. 10. It was recently supplied and erected by G.W.B. Electric Furnaces, Ltd., in the Leeds factory of the Yorkshire Copper Works, Ltd. Tube sizes varying from $\frac{3}{4}$ in. to 6 in. diameter are processed in this furnace.

The total length of the installation is 100 ft., of which the loading table takes up 25 ft., the heating chamber 20 ft., the cooling chamber 25 ft., and the unloading table 30 ft. Driven rollers extend the whole length of the unit, those within the heating and cooling chambers at a pitch of 6 in., those in the loading and unloading sections being at a pitch of 12 in. All the rollers have $4\frac{1}{2}$ in. flanges to guide the charge and, in the heating section and a portion of the cooling chamber, are fabricated from 18 : 8 chrome-nickel steel, while all others are of mild steel. The rollers in the heating and cooling chambers run in special self-aligning Morganite composition bearings which withstand heat and do not require lubrication, other bearings being normal self-aligning plummer blocks. The drive is transmitted from a single unit giving charge speeds of from 6 to 60 in./min. and driving through a common layshaft to chains and sprockets on one end of each roller shaft.



Courtesy of G.W.B. Electric Furnaces, Ltd.

Fig. 10.—Electric roller hearth furnace for annealing 1 ton/hr. of brass tubes.

The total electrical rating of 170kW is split into three zones, each governed by an Electroflo electronic indicating controller, while a 3-point recorder gives a positive check on thermal conditions along the installation. The electric supply was converted by transformers to 2 phase, 50 cycles, 4 wire ; one phase covering the roof and the other the hearth-heating elements. Further, in order to reduce power consumption when operating at lower temperatures and with a comparatively light charge, each of the three heating zones is supplied through a transformer with off-load tappings at four points, below full zone load. Protective devices include an adjustable thermostat covering each heating zone. For ease of maintenance and inspection of the furnace interior and strip heating elements, the roof is removable in sections. The cover plates of the water-jacketed cooling chamber are also removable.

Another recent plant by G.W.B. Electric Furnaces, Ltd., is a rectangular bell furnace installation, shown in Fig. 11, at the Brierley Hill Works of Richard Thomas & Baldwins, Ltd. It is for annealing silicon steel sheets under a protective atmosphere of burnt and cracked ammonia at temperatures up to 900° C. The whole installation comprises three furnace bells rated at 500kW in two zones, 12 charge bases, each with a gas-tight heat-resisting steel retort and three mild steel cooling hoods. Each base has a capacity of 45 tons of sheets and an effective dimension of 12 ft. × 6 ft. × 4 ft. high. Temperature control equipment includes two indicating controllers for each heating bell, while a 3-point recording instrument is provided for each base to give a positive check on each charge load throughout its heat treatment cycle.

Courtesy of G.W.B. Electric Furnaces, Ltd.

Fig. 11.—A rectangular bell furnace installation for annealing silicon steel sheets in a protective atmosphere.

As with normal annealing practice, bright annealing may be carried out in similar types of furnaces, provided arrangements are made for controlling the atmosphere in the furnace chamber and during the time of cooling. With the ordinary batch furnace the atmosphere can be controlled during heating, but provision for cooling in a controlled atmosphere is more difficult. It was with the object of overcoming this problem that the bell type

of furnace was developed and for bright annealing on a batch basis this type of furnace has become standard practice.

With this type of furnace, the charge is loaded on a stool on the hearth of the furnace, and is enclosed by a sheet metal cover which is sealed by sand or water around the hearth to form a completely gas-tight enclosure. Two or more hearths are provided with each furnace. Since the object is to obtain an oxide-free finish on the material treated, the atmosphere prepared for the heating chamber must depend to some extent on the material, but usually it is prepared from ammonia or town gas in a separate atmosphere generator, from which the furnace is supplied.

The bell-type furnace is applied to the bright annealing of coiled rod, wire, strip and tubing, and may be of the vertical or horizontal type. A large installation of the vertical type is shown in Fig. 12, which has been recently put into operation for the bright annealing of silicon steel strip in coils. The installation, which is by General Electric Co., Ltd., comprises six furnaces, each capable of taking a 20-ton charge, and a full complement of furnace bases and hoods. Each furnace has a maximum rating of 360 kW and is fully equipped for individual control.

Another bright annealing furnace, of the vertical cylindrical type, has been designed and built by General Electric Co., Ltd. for copper and copper alloy strip in coils, and is illustrated in Fig. 13. For this furnace the annealing pots are over 12 ft. deep. The furnace is rated at 270 kW and is designed for operation at temperatures up to 700° C.

Annealing of Malleable Castings

The production of whiteheart malleable iron castings by annealing in pots, surrounded by iron ore, etc., calls for a somewhat long heating, soaking and cooling cycle, and the high thermal efficiency and other desirable features of the portable cover furnace make it particularly suitable for this work. The Dowson & Mason furnace shown in Fig. 14, is heated by town's gas and operates at about 1,000° C. It can accommodate a total charge of 15 tons and the pots are easily stacked by overhead crane. Recuperation by thimble tubes, i.e., tubes with one end blanked into which is inserted

Courtesy of The General Electric Co., Ltd.

Fig. 12.—An installation of six vertical cylindrical bell-type furnaces for annealing silicon steel strip in a protective atmosphere.

Courtesy of The General Electric Co., Ltd.

Fig. 13.—A charged container being lowered into a vertical cylindrical furnace. The fan fitted to the pot head ensures rapid circulation of the atmosphere.

a smaller diameter tube, is used so that the air is blown through the inner tube and passes between the inner and outer tube to an opening in the refractory immediately below the gas jet. As each burner has its own recuperator element, a soft lambent flame is provided with air-gas ratio remaining constant although preheated air temperatures may fluctuate. The hot gases rise to the top of the hood and then pass downwards through flue ports at hearth level to an underground flue.

No major design changes have been made in Birlec elevator furnaces for the gaseous annealing of whiteheart malleable castings, but slight improvements have been incorporated in each new job. However, interesting application data have been obtained, particularly concerning the annealing of heavy section castings. In the furnace shown in Fig. 15, large axle box housings of up to 4 cwt. in weight and up to 4 in. in section are regularly annealed in 5-day cycles. Two and 3-day cycles are still used for thinner section components such as conduit fittings.

It is noteworthy that the Birlec elevator furnaces recently installed for annealing blackheart castings have not yet been engaged on large scale production annealing and any claims for them must necessarily be premature. The annealing process is similar to its whiteheart gaseous counterpart but the cycle is such that to obtain optimum thermal efficiency, two furnaces are installed, one for temperatures up to 1,000° C. and the other up to 750° C.

Hardening and Tempering Furnaces

Many hardening and tempering furnaces have been installed recently incorporating several improvements, particularly in low temperature treatment where the principle of recirculation of burnt gases in large volumes

Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 14.—A portable cover furnace for annealing whiteheart malleable iron castings by the pack method.

and at high velocity has been further developed. In this system the heat is generated in a separate combustion chamber and it is being applied for a number of purposes where accurate temperature distribution is of great importance, as in the case of many alloy steels and also aluminium alloys. Furnaces of this type differ fundamentally from ordinary direct-fired furnaces.

The large installation of mechanised heat-treatment furnaces, designed and built by British Furnaces, Ltd., as shown in Fig. 16, is in use for the hardening and tempering of ring gears and bevel pinions, etc., after carburising. The complete unit consists of a hardening furnace, oil-quench tank, wash chamber, tempering furnace and a spray-quench chamber, and the components are automatically conveyed from the charge end of the hardening furnace on to the final discharge table without any intermediate man-handling.

The conveying mechanism is rather unique as the whole sequence of operations is accomplished by means of an electrically controlled integral hydraulic system. The smaller components are loaded on to jigs carried in heat-resisting steel trays, while the ring gears are loaded direct on to the trays, as these have to be press-quenched, and are removed through a side discharge door at the end of the re-heat furnace. After a tray has been loaded, the operator pushes the tray off the loading station on to a Lowerator, which positions the tray on the hardening furnace roller track ready for entering the charge vestibule at the appropriate time. At the pre-set time cycle, the tray is pushed into the charge vestibule and then into the heating chamber in two stages, while a tray is also pushed on to a Lowerator table at the discharge end of the furnace heating chamber prior to quenching. On the Lowerator reaching its bottom position in the quench tank, a further pusher then moves the tray off the Lowerator table and by so doing, moves a further tray on to an elevator table which elevates the tray into position ready for its passage through the wash chamber, tempering furnace and spray quench chamber.

Each hardening furnace is indirectly heated by radiant tube heating elements situated above and below the furnace roller track and is purged with a prepared atmosphere to ensure "scale free" work. It operates on an output of 600 lb. of net work per hour at a temperature of 850° C.

Each tempering furnace incorporates forced convection heating in which the hot gases are fed through specially designed ducting into the heating chamber proper by means of large hot-gas circulating fans, and the furnace is designed to operate at temperatures ranging from 180° C. up to 650° C. The empty trays are returned from the discharge end of the tempering furnace back to the loading station on a gravity roller conveyor system.

Among the many electric furnaces that have recently been installed for these purposes is an installation of two combined hardening and tempering furnaces at the works of the Ford Motor Co., Ltd. They have been designed and built by McDonald Furnaces, Ltd. for the treatment of axle shafts for both cars and tractors. These two furnaces are of unique design and are the subject matter of patents pending.

Each furnace comprises two chambers, disposed one above the other, and adopted to provide successive heat treatment. The arrangement for mechanical handling the shoes comprises a pusher gear and interconnecting hoist at the charge end of each chamber. The operation is completely automatic and synchronised so as to establish an endless feed circuit or path for the shoes. By this arrangement the shoes, which pass through the heating chamber, are discharged through a chute on to the hoist. The axles are individually selected by the movement of the door hoist and removed to a cradle from where they are immediately spin quenched by the operator. The hardened axles are then placed on the shoes located on the hoist. The hoists at each end of the furnace are lowered to the bottom chamber and the shoes and axles are pushed into the tempering furnace. The shoes and axles discharged at the other end are then elevated to the top position, when the axles are removed and quenched, thus completing the cycle. In the case of axles for tractors, which weigh approximately 55 lb. each, a lever mechanism, operated by the action of the hoist, removes the axles from the shoes and places them on a conveyor fitted with water-spray cooling, allowing the shoes to return in the hoist to the elevated position. The endless circuit of shoe-travel disposes of any need to man-handle hot shoes.

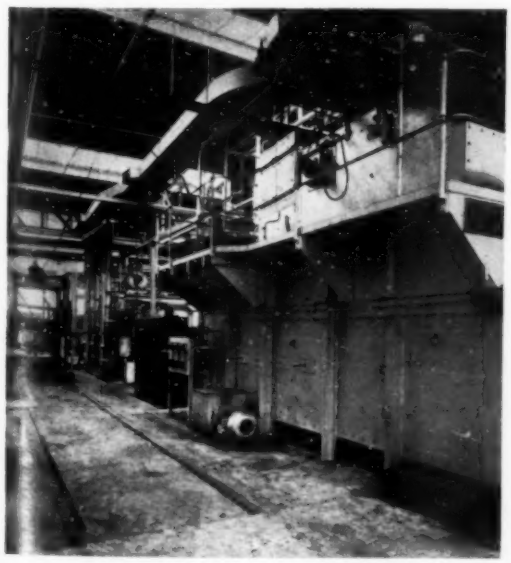
Courtesy of Birlec, Ltd.

Fig. 15.—Elevator furnace for the gaseous annealing of whiteheart malleable iron castings.

The whole plant, which is illustrated in Fig. 17, is operated by a strictly timed sequence control, and the operator is therefore unable to interrupt the flow of production, unless the emergency button is used. The furnace rating is 300 kW, distributed in eight independently controlled zones. The variation required in hardness of a certain class of shaft requires a considerable temperature differential across the width of the tempering chamber; for this reason the tempering chamber is split into two main longitudinal zones, each being subdivided into three separately controlled zones across the chamber.

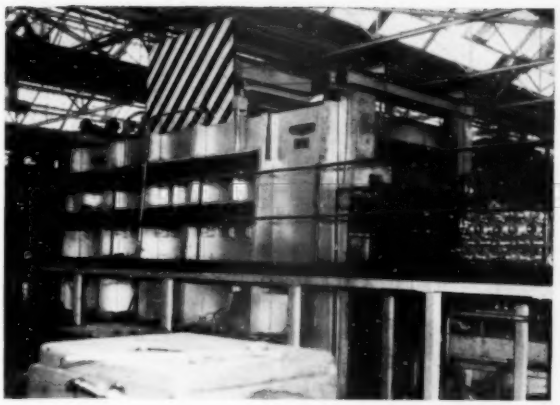
Few plant operations offer as great an opportunity for far-reaching economies as does heat treating. Particularly is this true of tools and dies which call for heat treating of a high order of accuracy. With a modern precision furnace it is possible to maintain specification hardening which will result in lower heat-treating costs, because rejects are substantially reduced; lower toolroom costs, because, with longer tool life and fewer rejects, fewer tools are needed; and lower production costs, because, with increased tool life, smoother operation is maintained over a longer period.

The Leeds and Northrup Vapocarb-hump furnaces are operating very successfully for this class of work. Although there has been no major change in the design of these equipments supplied by The Integra Co., Ltd., the method provides control over atmosphere, rate of heating and quench point. These three controls give the heat treater the controllability necessary for specification hardening. The equipment is supplied as a complete method of hardening, all the controls are built in and it is compact and rugged. In addition to the primary job of precision hardening, the equipment can be used to carburise and gas cyanide small loads. For these purposes the equipment provides atmosphere control, automatic temperature control and a record of time and temperature. Combined with the Vapocarb-hump method of hardening, the Homo method provides a completely co-ordinated system of tempering.



Courtesy of British Furnaces, Ltd.

Fig. 16.—A complete hardening and tempering plant for the heat treatment of ring gears and bevel pinions, incorporating automatic-handling facilities.



Courtesy of McDonald Furnaces, Ltd.

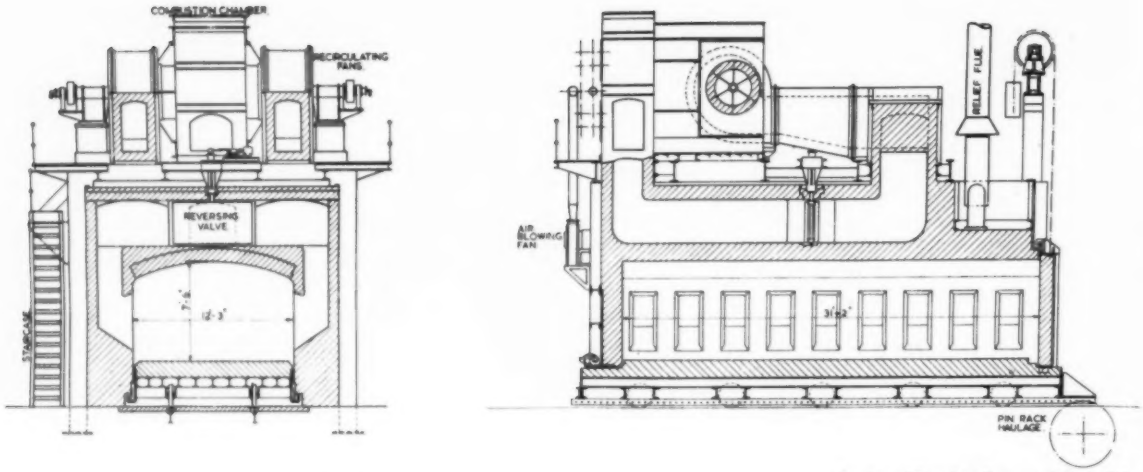
Fig. 17.—Combined hardening and tempering furnace designed for the treatment of motor car and tractor axle shafts.

In our May issue of last year reference was made to a modification in the Homo furnace to permit of the steam treatment of twist drills which greatly enhanced their useful life; this furnace has now been successfully applied to the steam treatment of high-speed steel tools. The Integra Co., Ltd. are also supplying these modified furnaces to manufacturers of sintered products. After metal compacts have been treated in the steam atmosphere the hardness figure is considerably increased.

Among other recent installations is a continuous chain-conveyor furnace for the treatment of highly-alloyed steel plates. This furnace, which has been designed and built by Brayshaw Furnaces & Tools, Ltd., is capable of a continuous output of 240 of these plates per hour varying in size from 17 in. square to 20 in. square by 19 gauge, heated to 1,070° C. It has a heating length sufficient to accommodate six plates with an additional four carriers at the loading end.

Heating is effected by a series of gas and air blast burners using town's gas at 8 in. water pressure in conjunction with air pressure at 18 in. w.g. The burners are arranged to fire directly into the work chamber, but in such a way that there is no direct impingement of the flames on the plates, and the products of combustion are exhausted from both ends of the furnace to ensure even heating conditions.

The furnace conveyor chain of mild steel is provided with belt tensioning device, and the chain is driven through an infinitely variable speed gear box. The chain mechanism, being remote from the heating chamber, is not subjected to any great degree of heat, but that part of the conveyor system actually passing through the furnace chamber is constructed of heat-resisting steel. The plates are supported on holders by point contacts only, thus preventing the possibility of uneven heating, and by means of a chute the plates are automatically delivered direct into a quench tank. The furnace roof is of the clamped removable type, allowing easy access to the working chamber for maintenance and repairs. Inspection holes, fitted with Pyrex glass, are provided at various vantage points in the sides of the



Courtesy of Brayshaw Furnaces & Tools, Ltd.

Fig. 18.—Large gas-heated recirculation type bogie hearth furnace for tempering steel forgings.

furnace to enable the furnace operator to inspect plates whilst they are passing the heating section.

Of particular interest is a large gas-heated recirculation type bogie-hearth tempering furnace designed and built by Brayshaw Furnaces & Tools, Ltd., and installed at the works of Hadfields, Ltd. It incorporates an indirect system of heating and is suitable for precision heat treating at low temperature—from 100 to 750° C.—to within ± 2½° C.

Furnaces of this type depend entirely upon the continuous recirculation at high velocity of large volumes of hot gases to achieve the extreme accuracies and the speed of heating for which they are designed. Such recirculation is accomplished by the incorporation of a separate combustion unit located on top of the furnace structure in which the products of combustion are generated, and then recirculated by powerful fans through connecting insulated ducts to the work chamber and load. Some idea of the principle of heating involved is indicated in the line drawing shown in Fig. 18.

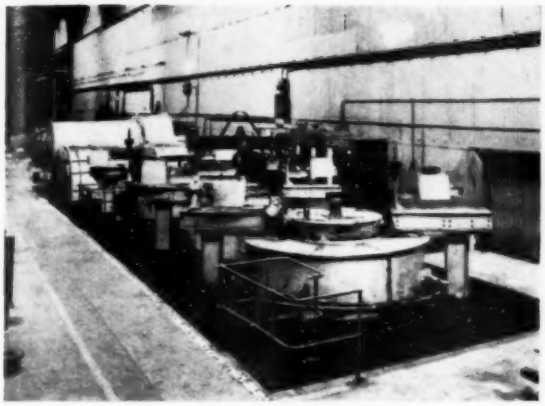
The combustion chamber, designed for use with either town's gas or galusha gas, in conjunction with low pressure air, is divided into two smaller combustion units each being separately fired and provided with permanently lit pilot flame: for very low temperature work, the furnace can be heated from one combustion unit only. The system of heat distribution applied is of the crossflow type in which the hot gases are recirculated from wall to wall across the furnace chamber, the flow direction of the gases being automatically reversed at a pre-determined rate which can be varied from a 3 min. to a 30 min. cycle. The furnace, which has a bogie hearth 30 ft. long by 12 ft. wide and a loading capacity of 45 tons, incorporates automatic control of the fully floating type used in connection with air and gas proportioning valve for the precise control of the furnace temperature.

Earlier in this article reference was made to the use of high frequency induction heating in the black bolt industry for heading: this method of heating is also being used for hardening and developments have shown that it can have a special value in the mass production industries. A typical example is the vertical shaft hardening machine shown in Fig. 19. In designing this machine Birlec, Ltd., have adopted a machine tool approach and have produced a heating unit with which heat treatment can be considered as a normal production operation on the main factory conveyor system without the need of routing it through a separate heat treatment section. The machine is loaded by placing the shaft in a V-guide; it is automatically lowered into its heating coil and after a preset time cycle, is water-spray quenched and raised for the operator to withdraw it. A particular production advantage is that distortion is virtually eliminated; it is also possible to harden selectively along the surface of the shaft.

For the bright hardening of miscellaneous small parts such as needles, watch parts, fish hooks, etc., the shaker hearth furnace is being advantageously used. The Range made by the Electric Resistance Furnace Co., Ltd., includes sizes from 6 in. wide hearths to 18 in. wide hearths to give outputs of from 30 lb. to 500 lb. bright

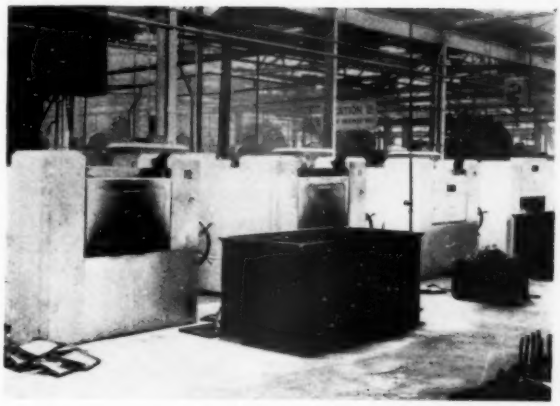
Courtesy of Birlec, Ltd.

Fig. 19.—Vertical shaft hardening machine in which the component is heated by high frequency induction.



Courtesy of Brayshaw Furnaces & Tools, Ltd.

Fig. 20.—Tempering units heated by high velocity recirculated products of combustion from the remote combustion unit seen in the background.



Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 21.—Part of a battery of horizontal "hairpin" furnaces used for the treatment of small parts.

hardened work per hour. Cracked town's gas is recommended to provide the furnace atmosphere. The nickel-chrome hearth plate has corrugations running longitudinally on the top surface which minimises any tendency for the load to "wander" on the surface. The hearth mechanism is pneumatically operated and provided with control valves connected to a time clock which is set to operate the hearth at pre-determined intervals. By adjusting the time interval and the stroke of the pneumatic cylinder, the heating time in the furnace can be adjusted to suit the particular charge. The work is discharged from the end of the hearth plate straight into the quench tank.

A vertical pit-type preheating, hardening and tempering plant has been installed in the works of Thos. Firth & John Brown, Ltd., by Brayshaw Furnaces & Tools, Ltd., which has a number of interesting features. The hardening plant comprises a direct-fired high temperature muffle furnace and a preheating muffle furnace, the latter being heated by the waste products of combustion from the high temperature chamber. Both units have a box brick muffle 4 ft. $1\frac{3}{4}$ in. dia. and a working depth of 7 ft. 3 in. The hardening furnace is divided into four zones, each separately controlled by a recording controller which has fully floating and proportioning control device with the additional feature of programme regulation. In addition, a 3-point recorder is provided for recording actual load temperatures. The burner equipment is suitable for consuming town's gas at 2–3 in. w.g. in conjunction with pressure air. All burners fire tangentially round the muffle to prevent the formation of hot spots on the box brick muffle. Each of the four zones of burners is fitted with gas and air proportioning valve to maintain the mixture setting throughout the range of burners.

A by-pass flue, adjusted by a handwheel operating dampers through a gear drive, regulates the flow of products of combustion to the preheating muffle, the brickwork of which is zoned to facilitate distribution of heat from the top to the bottom of the chamber.

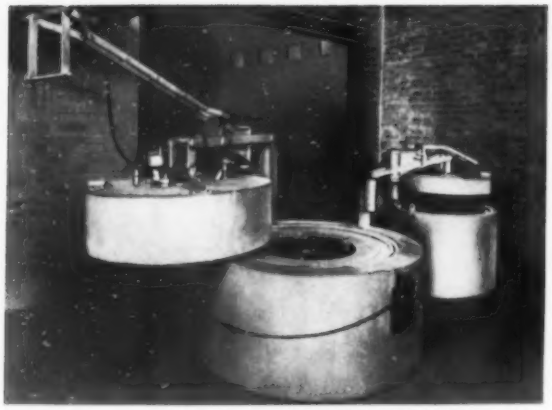
The tempering unit is of the recirculation type heated by high velocity recirculated products of combustion from a remote combustion unit, which is visible at floor level in the background of Fig. 20. This furnace is 3 ft. 9 in. dia. and has an actual working depth of 17 ft. 3 in. The tempering plant is suitable for operating at temperatures from as low as 100° C. up to a maximum of 750° C. Reversing mechanism for the recirculated gases is controlled through a time switch, the intervals of reversing being adjustable. A proportioning recording programme regulator controls the flow of recirculation gases, and a 3-point recorder is provided for load temperatures.

Part of a battery of Wild-Barfield horizontal "hairpin" furnaces used for the treatment of small parts at the Darlaston Works of Messrs. Guest, Keen and Nettlefolds, Ltd., is shown in Fig. 21. Note particularly the clean lines of these furnaces and the convenient location of the quench tanks. Furnaces of this type have a maximum working temperature of 1,050° C. with solid elements and of 1,150° C. with tubular elements. The standard range of four sizes has ratings from 36kW to 78kW. As will be noted, the door gear actuating the vertically sliding counterbalanced door is totally enclosed and is operated by a single handwheel. Each furnace in this installation is controlled by its own indicating automatic temperature controller which also records the treatment of each batch.

Gas Carburising Equipment

Although solid carburisers continue to be more widely used in the carburisation of ferrous metals, the advantages of gas carburising have led to its increasing use, particularly where relatively deep cases have to be treated and precise control of the case is necessary. An installation of this kind is that shown in Fig. 22 which is designed for gas carburising engine gear box parts. The parts are loaded into the furnace in baskets and are subsequently transferred to a separate chamber for cooling in a protective atmosphere. This furnace is rated at 50 kW and is provided with facilities for forced air circulation. It is a General Electric Company unit.

Some changes have been made to the Homocarb principle equipment for gas carburising. The changes concern the design of the furnace internals which now incorporate a sheet metal closed bottom retort with integral top trough. Also incorporated in the latest design is an improved combination fan housing the work support which is aero-dynamically designed with the special discharge jets which enable and powerful fan to circulate furnace atmosphere through the densest loads. The Integra Company are supplying a number of these



Courtesy of The General Electric Co., Ltd.

Fig. 22.—Pit-type gas carburising furnace with separate cooling chamber.

equipments to such users as The Austin Motor Co., Ltd. and Vauxhall Motors, Ltd.

A furnace for the gas carburising of rear axle gears has been installed by British Furnaces, Ltd. at the works of a leading British motor manufacturing firm, and has recently successfully completed its preliminary trials before going into full production. The furnace, which is about 42 ft. in length, has two tracks on which the work, loaded on trays, is pushed through. It is heated by gas-fired radiant tubes controlled in three zones, the first being the heating zone, the second the carburising zone and finally the diffusion zone, this latter being held at a lower temperature than the other two.

All the various pushers, vestibule doors, furnace doors, charger, etc., are hydraulically operated, the valves being electrically operated, controlled by a master clock, which makes the furnace operation completely automatic. Illustrations of parts of this furnace are shown in Fig. 23.

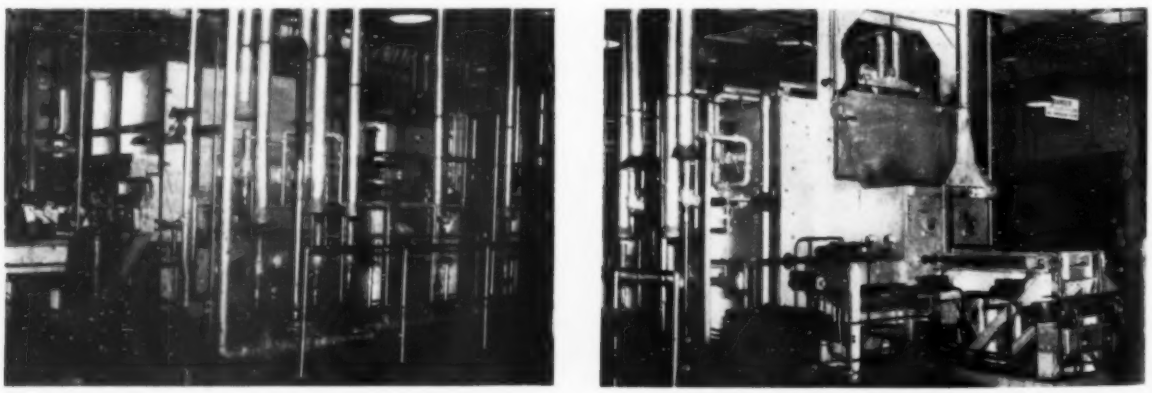
One interesting feature of this plant is that the carburising gas is prepared from town gas by passing a non-combustible mixture of air and gas over a heated catalyst. The endothemic reaction produces a gas which is essentially free from carbon dioxide and water vapour—dew-point −14° C.—without the necessity of removing them, and contains approximately 30% carbon monoxide, 48% hydrogen and the remainder nitrogen. This gas—RX gas, as it is called—is an ideal carrier gas, as it is itself a carburiser, and only requires the addition of a small percentage of hydrocarbon gas to produce a satisfactory case.

This furnace produces work carburised to a total depth of 0·040 in. in 6½ hours, that is 0·035 in. of hard case with up to 0·024 in. of eutectoid. Work of various kinds is to be carburised, some being press quenched, some hand quenched and some slow cooled. A slow cool zone is provided which fulfils the dual purpose of conveying the work trays and jigs back to the charge end as well. To enable close control to be maintained continuously, the instrumentation is elaborate and includes a recording dewpoint indicator and a gas analyser which indicates continuously the amounts of carbon dioxide—less than 0·2%—and methane—up to 2%.

New furnace designs which have been developed by the General Electric Co., Ltd. include a continuous carbo-nitriding furnace for processing engine gear box parts. This is a pusher-type furnace in which the gears are suspended in jigs from a cradle and traversed through the furnace by a hydraulic pusher.

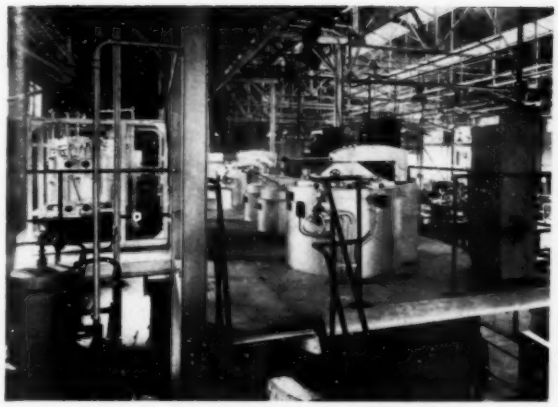
There are several interesting features about the gas carburising plant recently installed at the Plessey Co.'s Works at Ilford by Wild-Barfield Electric Furnaces, Ltd., and shown in Fig. 24. In order to bring the top of the furnaces to a convenient working height, and to save extensive excavating, a staging was erected round the equipment while the controllers, switchgear and gas preparation unit were mounted on the staging. Easy maintenance is thus facilitated by the accessibility of all components. On the right of the illustration is the gas preparation unit, while the switchgear and controllers are situated behind the furnaces, cooling pits and quench tanks. An overhead hoist is used to convey the loaded jigs and retorts to their various stations.

In operation, town's gas, direct from the mains, is fed to a compressor, through a flow meter to a special catalyst, through an air cooler to driers and then direct to the carburising retorts. The gas from the catalyst exit passes through the air cooler to silica gel driers, one only of which is used at a time so that the plant can be operated continuously. Regeneration of the silica gel is effected by a low temperature treatment in a



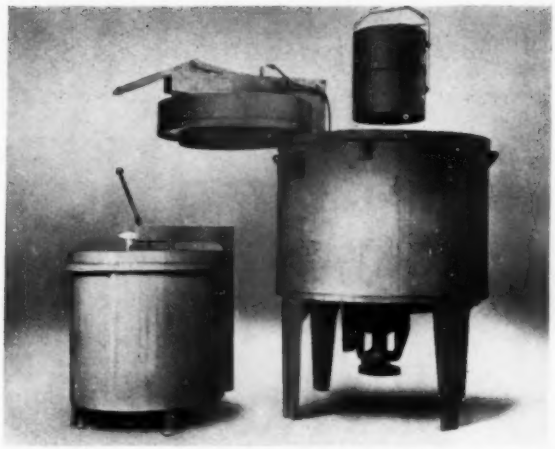
Courtesy of British Furnaces, Ltd.

Fig. 23.—Two views of a large furnace for the gas carburising of rear axle gears. It is heated by gas-fired radiant tubes in three zones.



Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 24.—Gas carburising plant built entirely above ground with elevated working stage.



Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 25.—Vertical batch type equipment for gas carburising, with separate cooling chamber.

small forced air circulation furnace. After passage through the drier, the gas travels via an inferential meter to the carburising retorts. Standard equipment is used for gas flows up to 200 cu. ft./hr. which will cope with charges up to 15 cwt. in a retort 2 ft. 3 in. dia. and 4 ft. 6 in. deep.

The retort is purged and lowered into the furnace controlled at the specified carburising temperature and, after adjusting the gas flow read on the flow meter, no further attention is required until the "active" carburising period is finished. The compressor is then stopped and the outlet valve of the retort closed. The preparation can then be used to purge other retorts while the first charge is completing the diffusion period.

Another vertical batch type equipment for gas carburising is shown in Fig. 25. This furnace, which is by Electric Resistance Furnace Co., Ltd., is designed to accommodate a nickel-chrome charge carrier within a gas-tight retort, and at the bottom of the retort is located a fan to ensure circulation of the atmosphere. The lid of the furnace is arranged with a seal ring on its outer edge to support the cast nickel-chrome cover of the retort. The complete equipment comprises a furnace with automatic temperature control·gear and temperature recorder, charge carriers, and a slow cool chamber and/or a quench tank.

Alternative methods of providing the necessary atmosphere are available and include (*a*) endothermic gas (cracked town's gas plus propane from cylinders) for carburising; (*b*) a liquid hydrocarbon unit, comprising a complete pump unit to drip the hydrocarbon into the furnace at regular intervals; and (*c*) if the furnace is to be used for carbo-nitriding, then to either of the above atmospheres ammonia from cylinders is introduced into the furnace.

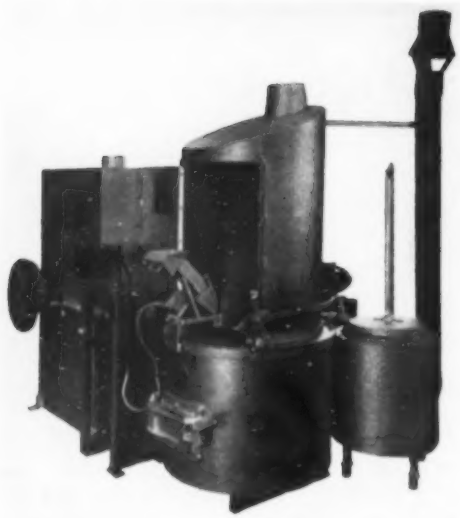
Although a considerable amount of project work has been undertaken by Birlec, Ltd., on equipment for continuous gas carburising, major interest still centres on the pit-type batch units and a battery of five units installed by this firm is shown in Fig. 26. Special care continues to be paid to the provision of suitable carburising atmospheres and production tests have been satisfactorily completed on a drip-feed system: two units will shortly be put into service in which this method is adopted. Use has also been made of an atmosphere derived from a Birlec endothermic generator as a carrier gas. This generator provides a neutral carrier gas which is particularly suitable where a long diffusion period or closely controlled carbon content is required, the readily adjustable carbon potential ensuring these conditions.

Salt Baths

The use of salt baths for the heat treatment of a wide range of materials has been popular for many years and despite developments of other types they continue to be favoured for many purposes. Recently, success has attended the efforts to reduce still further the operating costs on baths containing cyanide, used for surface hardening, or for applying up to 0·01 in. depth of case to mild and alloy steels. Work conducted by Imperial Chemical Industries, Ltd. has shown that "Cassel" C.S. 700 baths maintained at only 10–15% sodium cyanide are capable of applying case depths of around 0·01 in., with hardnesses of V.P.N. 700–850, to medium carbon alloy steels, such as En 18 and En 24. The depth-hardness characteristics of the case applied to these

Courtesy of Birlec, Ltd.

Fig. 26.—A battery of five pit-type units for gas carburising by the batch process.



Courtesy of Imperial Chemical Industries, Ltd.

Fig. 27.—A modification of the "Cassel" T-type automatic salt bath furnace.

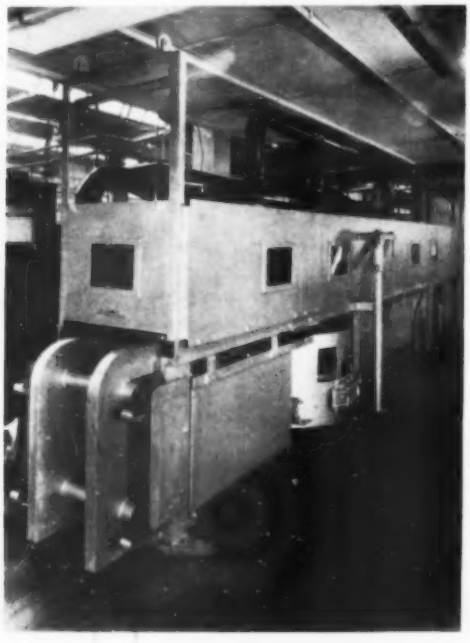
steels are sufficiently good to allow grinding on gears to be accomplished, where required, whilst maintaining a satisfactorily high surface hardness after grinding.

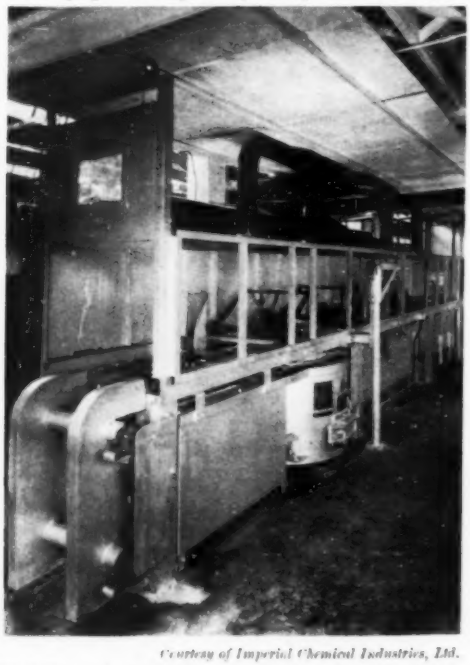
Enclosure of salt bath furnaces to eliminate fume from the atmosphere surrounding the furnaces, thereby improving working conditions, is being actively pursued. The fitting of canopies to existing installations is advocated where possible, and new types of "Cassel" furnaces are available in which furnace and quenching tanks are totally enclosed under a common canopy. Transfer from one stage of the process to the next can be made fully automatic as in the "CA Automatic" and "T" type automatic furnaces. A cheaper modification of the latter is the furnace illustrated in Fig. 27, several of which are now installed and working. Small parts to be hardened are poured through the chute in the front of the canopy into a ladle already immersed in the cyanide salt bath. By operation of a press-button control this ladle is caused to swing on a fulcrum and empty the work into the quench, the ladle then being returned to its position in the melt to receive the next charge of work. Transfer of the work from the quench into a waiting container is accomplished by operating the handwheel on the extreme left of the illustration.

The austempering process is being widely accepted amongst manufacturers of carbon steel springs and clips, which are of relatively thin section. Some parts are austenitised in muffle furnaces, then quenched and transformed in a salt bath. Other parts are both austenitised and quenched transformed in a salt bath. A recently installed "Cassel" fully automatic "CA" type plant following the latter procedure is shown in Figs. 28 and 29. Fig. 28 shows the exterior of the totally enclosed furnace as it appears during normal operation, whilst in Fig. 29 the front panels of the canopy have been removed to reveal jig loads of work being passed through the different stages of the process, including preheat, W.S. 720 salt bath for austenitising, T.S. 150 salt bath for quenching/transforming, and water wash.

Furnaces for Technical Colleges

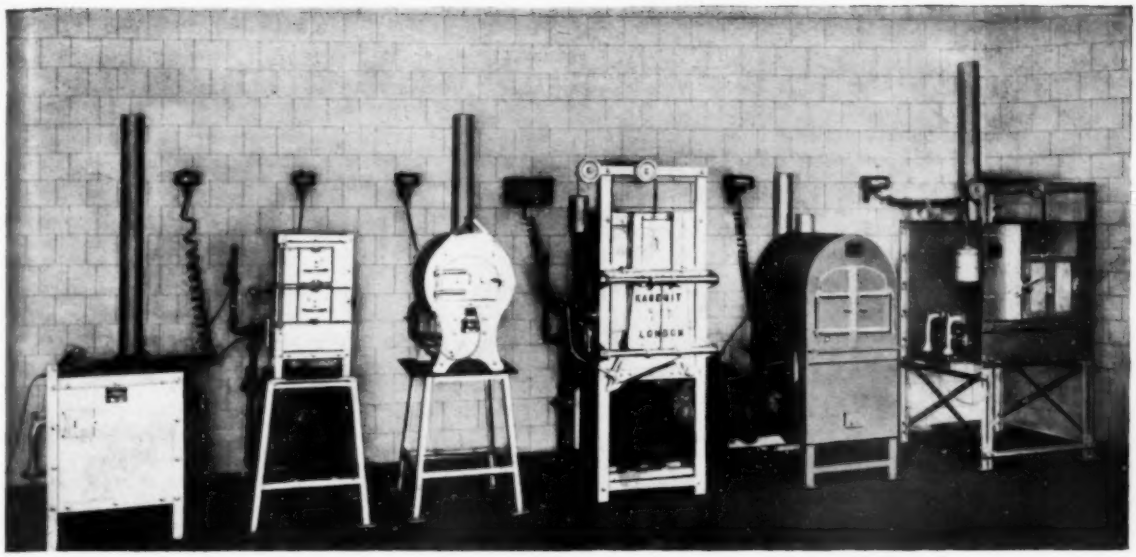
In our May issue last year attention was drawn to the importance of heat-treatment installations in university and technical college workshops or laboratories. Many types of equipment, specially designed for carrying out





Courtesy of Imperial Chemical Industries, Ltd.

Figs. 28 (left) and 29 (right).—A recently installed "Cassel" fully automatic CA-type plant for the heat treatment of steel springs and clips. Fig. 28 shows the exterior of the totally enclosed plant, whilst the front panels of the canopy are removed in Fig. 29.



Courtesy of Kasenit, Ltd.

Fig. 30.—A range of heat treatment furnaces suitable for technical colleges.

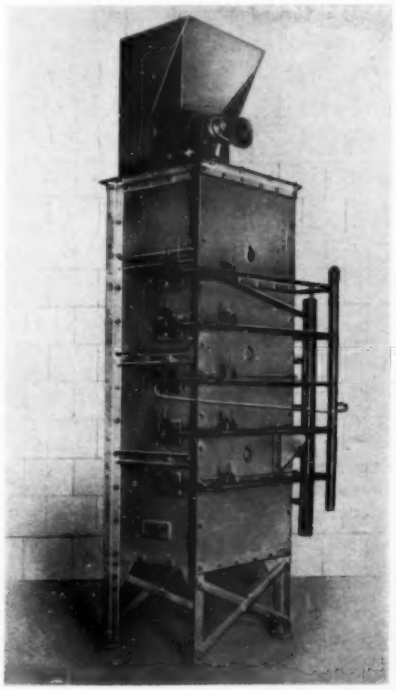
various treatments, are available. In addition to the construction of their standard types of salt baths, tool hardening and tempering furnaces, and plate heating furnaces, Kasenit, Ltd. make a speciality of small installations for instructional use and have supplied a full range of gas-fired units for this purpose.

Exfoliation of Vermiculite

The importance of proper insulation of industrial furnaces to make the most efficient use of the heat generated has long been recognised. For this purpose vermiculite is now being used extensively. Of the many insulating materials employed vermiculite is the most recent and has such remarkable properties that its use as an insulating material, particularly for high temperatures, is proving to have outstanding merits. The best qualities bulk 6 lb. or less per cub. ft. after being exfoliated, in which form it is used for making bricks and tiles, many thousands of which are used in the insulation of heat-treatment furnaces. To exfoliate vermiculite a number of furnaces have been developed one of which is being manufactured by Kasenit, Ltd. which is suitable for heating by gas or oil fuel. The vermiculite is fed by a worm feed into a nickel-chromium retort in which a number of baffle plates are fitted to avoid a direct fall through of raw material. The retort is heated on the outside by gas or oil burners to a temperature of around 900° C., and this temperature can be automatically controlled if desired. The exfoliated product is allowed to drop on the floor and after a few minutes is drawn away by suction to hoppers for grading and packing. Kasenit have installed twelve of these furnaces (Fig. 31) and have orders in hand for another three.

Acknowledgments

Owing to pressure of work in other directions a number of well-known builders of heat treatment plant have been unable to supply us with details of their latest developments and, in consequence, this article is not quite so comprehensive as we would have wished. We are, however, greatly indebted to those firms who have supplied information and photographs, and we would express our grateful appreciation to them, and to the firms in whose works the various items of plant are installed for permission to publish the details and illustrations.



Courtesy of Kasenit, Ltd.

Fig. 31.—A furnace designed for the exfoliation of vermiculite which is used as an insulating material in many heat treatment furnaces.

New and Revised British Standards

Oxy-Acetylene Welding of High Temperature and High Pressure Pipelines (B.S. 1821 : 1952)

Price 6s. Post Free

This is the first of a series of standards being prepared for the welding of pipelines, and covers pipelines for service conditions in which the pressure exceeds 250 lb./sq. in. and/or the temperature exceeds 425° F. (220° C.). The standard lays down the conditions for shop and site welding of joints in such steel pipelines and fittings up to and including 20 in. diameter, and is divided into four parts.

Part 1 defines the parent metals and specifies the types of filler rods, welding technique, general precautions and qualifying tests for welders. *Part* 2 deals with butt joints and specifies the method of preparation and requirements for the completed welds. This section covers not only plain butt welds but also flanges and bends, both gusseted and cut-and-shut. *Part* 3, for branches, includes details of preparations for the set-on and set-in types. Sleeve welds are covered in *Part* 4. The standard is amply illustrated by line diagrams and by photographs of satisfactory and unsatisfactory welds.

Nickel Clad Steel Plate (B.S. 1822 : 1952)

Price 2s. Post Free

This British Standard specifies steel plate to which a layer of nickel is integrally and continuously bonded on one or both sides. The base steel is required to comply with B.S. 1501, –151, –154, or –157. A high purity nickel is specified and tests are included to ensure efficient bonding between the nickel and the steel.

Nickel Silver Strip and Foil for the Telecommunication Industries (B.S. 1824 : 1952)

Price 2s. Post Free

This new British Standard forms part of a series of standards for nickel and nickel alloys in various forms and has been prepared to meet the special requirements of the telecommunication industries, particularly the telephone industry. During drafting, the specification developed by the manufacturers of telephone equipment and the producers of nickel silver strip, and adopted by the Post Office Engineering Department, was of great assistance. The standard lays down chemical compositions, temper grades, mechanical properties and tolerances on dimensions and specifies the procedure to be adopted in selecting test pieces and carrying out tests. Details are also given in regard to test certificates and independent tests and an appendix gives a summary of the information to be given by the purchaser in enquiries and/or orders.

Determination of Cadmium in Copper-Cadmium Alloys (electrolytic method). (B.S.1825 : 1952)

Price 1s. 6d. Post Free

This standard is published in response to a request for a British Standard method for the determination of cadmium in straight copper-phosphorus-cadmium alloys, as used in the manufacture of trolley and contact wire for electric traction and specified in B.S.23 ' Trolley and contact wire for electric traction.' The method is suitable for cadmium contents up to 2 per cent. and specifies reagents, recommended methods of sampling and the test procedure.

Colour Code for Twin Compensating Cables for Thermocouples. (B.S.1843 : 1952)

Price 1s. Post Free

This code provides for an indication of the nature of the thermo-couple with which the compensating cable is intended to be used, and also the polarity of the individual conductor. These compensating cables are a pair of wires having such Temperature/E.M.F. characteristics relative to the thermo-couple with which the wires are intended to be used that, when properly connected to the thermocouple, the thermocouple reference junction is in effect extended to the other end of the wires.

Methods for the Sampling of Ferrous Metals and Metallurgical Materials for Analysis, Part 1. Iron and Steel. (B.S.1837 : 1952)

Price 2s. 6d. Post Free

This standard is intended for use in conjunction with B.S.1121 ' Methods for the analysis of iron and steel ' and those specifications which include clauses governing chemical composition and sampling. Section 1 sets out the general requirements, Section 2 deals with liquid iron and liquid steel, Section 3 covers the sampling of pig, cast iron and wrought iron, and Section 4 includes the sampling of steel in the form of ingots, castings, blooms, billets, slabs, heavy sections, plates, light sections, bars, rods, wire, sheet, strip and tubes. The methods are those which have been found most satisfactory in practice. As is the purpose of the methods of analysis specified in the various parts of B.S.1121, the standard is primarily intended for referee purposes and should be considered as a guide to sound sampling procedure rather than as a rigid specification.

Filler Alloys for Brazing (B.S.1845 : 1952)

Price 2s. Post Free

This new British Standard supersedes the two previous standards dealing with filler alloys, namely, B.S.206 : 1941, " Silver solder (grades A, B and C) " and B.S.263 : 1931, " Brazing solder (grades AA, A and B)." When B.S.1723, " Brazing " was in preparation, it was decided to combine B.S.206 and B.S.263 and to extend their scope to include filler alloys used for all common brazing operations. As the same identification letters were used in B.S.206 and 263 for different materials, all the alloys covered by the present standard (B.S.1845) have been given " type numbers " to avoid confusion. In order to facilitate the transition from the use of the two previous standards to the adoption of B.S.1845, a table is included which correlates the old and new alloy references. The requirements for the alloys covered by the old standards remain unaltered and in addition, requirements are given for four new alloys, viz. a copper-silver-phosphorus alloy, a copper-phosphorus alloy and two brazing brasses.

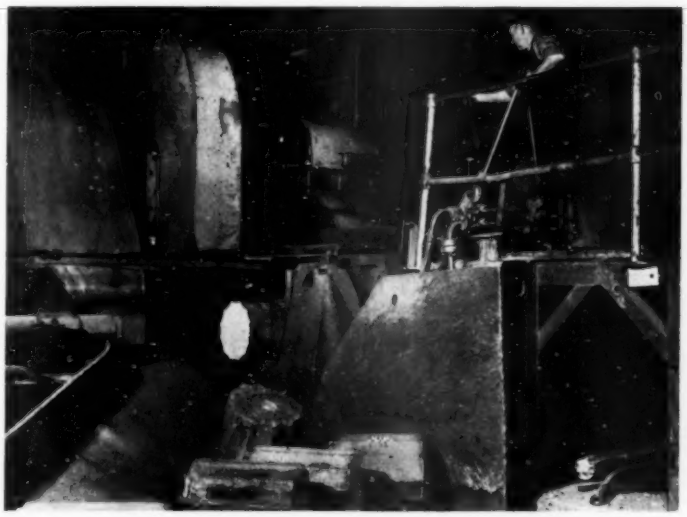
Copies of these standards may be obtained from the British Standards Institution, Sales Department, 24, Victoria Street, London, S.W.1.

Wheel Production at Steel, Peech and Tozer

Increased Output from New Plant Installation

THE production of tyres and wheels for railway rolling stock calls for specialised plant, and it is not surprising, therefore, that there are only a few concerns in the country equipped for this type of work. The wheel plant of one of these, Steel, Peech and Tozer, has recently been reorganised and new equipment installed. Depending on the length of run on a particular design of wheel, the ¾-acre plant can produce up to 180/200 solid wheels or discs per shift or, based on a 17-shift week, 3,000/3,500 per week.

Briefly, the manufacturing procedure comprises the following sequence of operations. The ingots are split into suitably sized blocks which, after heating to forging temperature, are formed into rough wheel blanks under a 6,000-ton press. The blanks are then reheated, rolled in the wheel mill, and pressed to final shape in a 1,500-ton dishing press.



Horizontal double-acting ingot breaking machine.

Ingot Breaking

Ingots of the required dimensions and steel quality are supplied by the melting shop and are carefully examined for surface defects, which are removed by a de-seaming torch after the ingots have been split into blocks. This latter operation is carried out on a horizontal double-acting ingot breaking machine, capable of breaking ingots up to 17 in. diameter into lengths not less than 1¼ times their diameter. It consists essentially of a massive crosshead, supported on anti-friction rollers and actuated by a steel eccentric securely keyed to a large high tensile forged steel shaft. The crosshead is driven through gears by a 100 h.p., 970 r.p.m. induction motor which drives by belt on to a large flywheel. A hand-operated clutch, provided for engaging the crosshead, is designed so that the machine stops at the middle of the stroke, and it is thus not possible for it to stop with the crosshead in contact with the ingot. The main body of the machine carries two pairs of hard steel breaking blocks which are adjustable to varying centres. They are also adjustable in height, by means of wedges and strong screw gear, to give the correct setting for breaking the ingots. Prior to breaking, a series of shallow nicks, each extending some one-third of the way round the ingot, is burnt in the surface by a cutting flame. These are so spaced by means of an adjustable template that each resulting block is of the correct weight to form a wheel.

Block Re-heating

After removal of surface defects, the blocks are loaded on to the bogies of a Wincott continuous gas-fired counter-flow furnace. The furnace consists of a preheating zone to accommodate nine bogies, a heating and soaking zone to accommodate four bogies, and a cooling zone to accommodate two bogies: as each bogie normally carries nine blocks, the furnace capacity is 117 blocks.

The bogies are propelled through the furnace by an electrically-operated double-rack type pusher, which can exert a thrust of 20 tons and has a stroke of 9 ft. 6 in. There are two bogie transfer cars, one at each end, and limit switches are used for these and for haulage of the bogies on the external return track.

During the time taken to travel through the furnace—some 5 to 7 hours—the blocks are thoroughly heated to a uniform temperature of 1,200° C. They are then lifted from the bogie by a Wellman 25 cwt. ground type charging machine and transferred to the 6,000-ton forging press via a whirling-chain type descaling machine which removes the scale from the top and bottom of the block.

Wheel Forging

The 6,000-ton Davy-United forging press is of the single cylinder vertical four-column type arranged for operating by two 600 h.p. hydraulic pumps and air-loaded hydraulic accumulator with a hydraulic intensifier.

The press is specially designed for wheel forging and is equipped with hydraulic gear for moving the slabbing and finishing anvils in and out of the press. There is also a hydraulically-operated swinging holder for the top slabbing tool pivoted on one of the columns, and mechanical handling gear for the wheel blanks. This gear consists of two gripping arms with forked fingers at

The wheel rolling mill in operation.

the ends working in the narrow space between the press columns, one at each side. The lifting of the gripped blank is effected by the movement of the press crosshead, and as the gear is attached to the crosshead, the fingers grip the piece at a suitable height, whatever may be its size and also form a convenient means of centring the piece in the press.

Power is supplied by two 6,000 h.p. electrically-driven horizontal 3-throw hydraulic pumps having 3 rams each 4¼ in. diameter, 15 in. stroke, speed 120 r.p.m., and capable of a theoretical delivery of 280 gal./min. against a working pressure of 3,000 lb./sq.in. Each pump is driven through a double-helical single reduction gear, the speed of the motors being 720 r.p.m.

An air-loaded hydraulic accumulator included in the circuit has a useful water capacity of 300 gallons, a total volume of air and water of 520 cu. ft., and air and water pressure of 3,000 lb./sq.in. There are two water bottles and five air bottles and the control gear is arranged for by-passing the water delivered from the pumps according to the position of the water in the accumulator, the pumps running continuously. A safety control is arranged to cut out the pumps at the high level and to shut the accumulator stop valve at the low level, if the normal control instruments fail. In order to provide the 6,000 lb./sq.in. pressure used in the final forging operation, the main cylinder of the press is interconnected with the high pressure cylinder of a 2 : 1 intensifier.

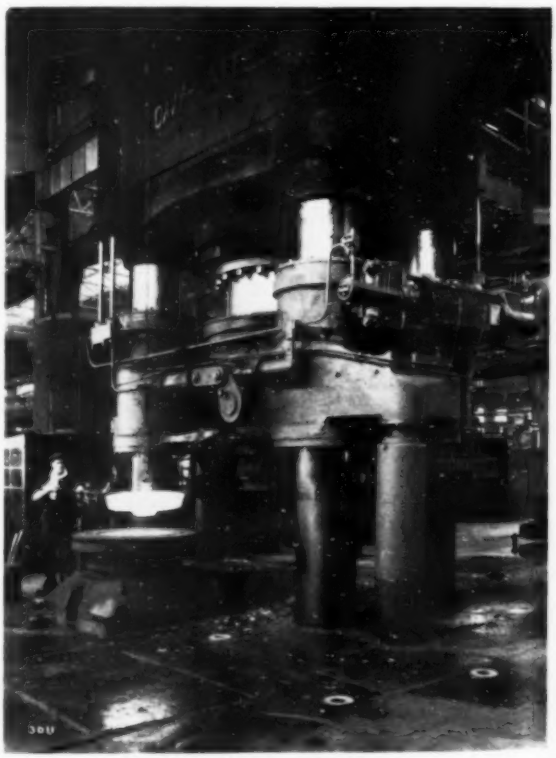
The exact procedure at this stage of manufacture may vary according to the type of wheel produced, but the following is typical. The block is placed on the slabbing anvil and the anvil is then moved under the press. The top slabbing tool is next swung under the press and a light squeeze is made which breaks the scale, and the scale is then blown off by compressed air. The block is then pressed into a blank in a ring hanging from the top slabbing tool. The top slabbing tool is then lifted and the blank ejected from the ring by the press crosshead into the forming die which has been brought into position by the sliding table, after which the slabbing tool is swung away.

The partly formed blank now being with the forming die, the press crosshead carrying the top forming tool makes the final pressing. This last pressing stroke is one in which the full power of the press (6,000 tons) is brought into use. The forged wheel is then punched and finally lifted by crane for transference to the re-heating furnace. The resulting wheel forging has the characteristic shape of a wheel, but it is thicker and smaller in diameter than the finished product.

Wheel Rolling

The forging is charged by a second Wellman machine into the Wincott re-heating furnace which is capable of heating more than 30 blanks per hour from 1,100°–1,250° C., depending on size and weight. The furnace is fired by coke oven gas (calorific value of 500 b.t.u./cu. ft.) at 5 lb./sq. in. pressure. When the forging is uniformly heated to the required temperature for rolling, it is withdrawn from the furnace and placed in the Davy-United wheel mill. The wheel is located and supported in the mill, which is of the vertical type, by a mandril through the bore, and the five rolls (two web, two side or edging, and one tread) combine to roll the wheel blank to the correct finished diameter and thickness. Water is sprayed on the wheel during rolling, so that no scale is rolled into the surface.

The mill is designed for the production of solid wheels from 18 in. up to 4 ft. diameter and up to 7½ in. face. It



6,000-ton wheel forging press.

is also suitable for gear wheels up to a width of 6½ in. on the rim. Each web roll is shrunk on to a spindle which is driven from a universal spindle by a 500 h.p. variable speed motor, and each web roll assembly is moved in and out to the centre line of the mill by means of a piston-type ram and cylinder, the ram having an extended tail-rod which is screwed and fitted with nuts to provide an accurate method of limiting the forward and return strokes.

It is essential that the web rolls move in towards each other at an equal rate when rolling the wheel, and this is accomplished by fitting each web roll ram with a separate pump, special metering valves being provided to control the fluid so as to adjust accurately the speed of the rams. The tread roll is equipped with a smaller ram and locking nuts.

Dishing

On completion of rolling, the wheel is transferred by a third Wellman charger to the dishing press, which is a conventional type forging press modified to perform this operation. This 1,500 ton press is operated from the pumps and air-loaded accumulator, which also operate the 6,000 ton press. It has a sliding table to bring the wheel in the centre line of the press crosshead. The dishing operation presses the boss into the correct position relative to the tread and gives the web of the wheel the desired conical shape.

Heat Treatment

The nature of the heat treatment given depends on the customer's specification, but the majority of solid wheels supplied are rim-sprayed. In this process, the wheel is first heated to a temperature of about 850° C. in a Wincott walking beam furnace which is fired by 28 low pressure burners of the Eddy Ray type suitable for coke oven gas. On removal from the furnace, it is placed on a rotating table in which it is spun for a pre-determined time at constant speed. During this operation, the rim is sprayed by means of a series of fixed jets located round the circumference of the table. No water is allowed to splash on the web of the wheel since this might give rise to local hard spots. This rim spraying treatment gives a hard-wearing tread. Apart from inspection and machining, the wheels are now complete.

The Iron and Steel Institute

Annual General Meeting in London

THE Annual General Meeting of the Iron and Steel Institute was held in London on Wednesday, 30th April and Thursday, 1st May, 1952. The Wednesday morning session, comprising the Business Meeting, the Presidential Address and the Sixth Hatfield Memorial Lecture, delivered by Professor E. N. da C. Andrade on "The Flow of Metals," was held in the lecture theatre of the Royal Institution, Albemarle Street. The technical sessions were held at the Offices of the Institute in Grosvenor Gardens; the papers presented for discussions were detailed in the announcement of the meeting in our April issue.

On the Wednesday evening, a very successful Dinner was held at Grosvenor House, Park Lane, when the attendance approached the four figure mark. The toast of The Iron and Steel Institute and Industry was proposed by Lord Brabazon of Tara, Capt. H. Leighton Davies (President of the Institute) responding. Of the many distinguished guests present, Mr. James Mitchell (Hon. Treasurer of the Institute) singled out a few for especial mention in proposing The Guests, a toast which was responded to by Lord Mackintosh of Halifax and Mr. Lincoln Evans.

Business Meeting

The retiring President, Mr. R. Mather, referred to the deaths, since the last General Meeting, of His Majesty, King George VI, Patron of the Institute, and of Mr. W. J. Brooke, an Honorary Vice-President with a record of long and faithful service to the Institute and Industry, and Sir Andrew Duncan, whose direct connection was of more recent origin, but who had given extremely valuable service to the Industry in his capacity as independent chairman of the Executive Committee of the British Iron and Steel Federation.

In welcoming visitors from Austria, Belgium, France and the United States, Mr. Mather made special reference to Dr. Oberegger of Austria, who had made such a large contribution to the success of the Special Meeting held there last September.

Following the adoption of the Report of Council and Statement of Accounts for 1951, the President made the following presentations :—

The Bessemer Medal for 1952 to Mr. H. H. Burton, C.B.E. (English Steel Corporation, Ltd.) in recognition of his distinguished services to the steel industry and to metallurgy, with particular reference to the development of alloy steels and heavy forgings.

The Sir Robert Hadfield Medal for 1952 to Dr. L. Reeve (Appleby-Frodingham Steel Co.) in recognition of his contribution to the science and practice of ferrous metallurgy and, in particular, his researches on the weldability of low alloy steels.

The Williams Prize for 1951 to Mr. J. A. Bond (Appleby-Frodingham Steel Co.) and Mr. T. Sanderson (Workington Iron and Steel Co.) for their paper on "Full-Scale Blast Furnace Trials."

A cheque, to which members had subscribed as a mark of appreciation of his long and helpful service, was then presented to Mr. Richard Elsdon, who retired at the end of last year from his position as Librarian after 48 years service with the Institute. In making the presentation, Mr. Mather said that Mr. Elsdon had been nominated an Honorary Member and Council also proposed to arrange for a portrait of him to be painted and hung in the library, as a permanent reminder of his services.

Details of the changes in the Council since the last General Meeting, were given by the Secretary, who then announced that :—

(*a*) An Andrew Carnegie Scholarship award of £150 had been made to B. Cina (Sheffield University) (Second Grant) for work on "The Effect of Cold Work on the Gamma-Alpha Transformation Characteristics of three Fe–Ni–Cr Steels."

(*b*) A Special Meeting would be held in Swansea from 7th to 10th October, 1952.

(*c*) The Autumn General Meeting would be held in London on 26th–27th November, 1952.

Presidential Address

Following the induction of the new President, Capt. H. Leighton Davies, C.B.E. (Assistant Managing Director of the Steel Company of Wales, Ltd.), Mr. Mather vacated the Chair, and Capt. Leighton Davies delivered his Presidential Address on "The Development of the Tinplate Trade."

The President said his own experience had been gained in both the productive and commercial sides of the tinplate industry, and it seemed fitting, therefore, that his Inaugural Address should have as its main theme that vital core of the industrial life of South Wales. The first paper on the tinplate industry had been given to the Institute by Mr. Flower in 1886, and Sir Charles Wright dealt with the subject in his Presidential Address in 1931, but since the hand-operated method of making tinplate was now passing to complete mechanisation, it was appropriate that he should bring the history of the industry up to date by adding a further chapter. Capt. Leighton Davies then proceeded to trace the development of the manufacturing methods through the three main periods: (*a*) 300 B.C.–A.D. 1727—Hammer reduction with hand pickling, tinning and cleaning; (*b*) 1728–1925—Hot rolling in pack form with hand, machine, and automatic tinning; and (*c*) 1926—present day—Rolling in strip form with automatic hot-dip tinning and electrolytic tinning. The last phase was illustrated by particular reference to the latest installation at the Trostre works of the Steel Company of Wales, at Llanelly. It is impossible to deal adequately with this part of the Address in the space available; we shall confine our attention, therefore, to the concluding section dealing with future developments.

Future Developments in the Tinplate Industry

In very early times, said the President, tinplate was used mainly as a building material, or for open vessels and ornaments. But with the advent of canning for the preservation of foodstuffs and other perishable materials, it found its real use. In the many years during which tinplate had been manufactured, only during the last fifty had there been the most radical changes in methods.

At the outbreak of war, in 1939, rolling in strip form had become almost universal in the U.S.A., and one hot-and-cold strip mill was in production at Ebbw Vale, in South Wales. Various countries on the Continent were also developing on the same lines. Before that time most of the plates exported from the U.K. (about 400,000 tons per annum) were hot-mill rolled, but by an economic arrangement with the U.S.A., our foreign buyers, especially South America, took their supplies from America in the form of cold-rolled plates. The foreign can-makers therefore adjusted their plants to suit that type of plate and acquired a preference for its better stamping qualities. Hence, to be able to compete in export trade with America it became imperative that strip rolling should quickly supersede the old pack method in this country.

In 1947, therefore, the erection of the second cold-reduction plant was started at Trostre, in Llanelly, by the Steel Company of Wales, Ltd., the hot mill for supplying the coil being built at Port Talbot. This was likely to be followed by a third cold-reduction plant and also by the reconditioning of the original plant at Ebbw Vale to produce a greater output. It was anticipated that those three plants would produce sufficient tinplate to cope with the total future demand, both for home consumption and for export, of between 20 and 25 million boxes per annum; i.e., about one sixth of the present world production.

While those developments had been taking place, further experiments in still more modern methods of production had continued, especially in America. The following items were among those that were being, or would be, investigated: (1) continuous casting of strip in tinplate gauges; (2) powder rolling of strip in tinplate gauges; (3) mechanical descaling instead of wet pickling; (4) development of cluster and planetary mills; (5) development of the 5-stand cold-reduction mill as a continuous unit, with welder, looping pits, or towers at either end, and shear and recoiler at the exit end (thus requiring lower-powered motors with lower speeds for equivalent outputs); (6) possibility of higher working speeds; (7) coupling of two or more of the present continuous operations; (8) abolition of cleaning by wet detergents and its replacement by a combination of a cleaning operation with the annealing treatment preceding continuous annealing; (9) continuous annealing by either the horizontal or the vertical method, preceded by electrolytic cleaning to take the place of the present separate cleaning unit with batch annealing; (10) production of strip with 'universal' temper by continuous annealing; (11) continuous hot-dip tinning of wide strip, covering coatings from ¼ to 2 lb. per box; (12) sale of tinplate (both electrolytic and hot-dip) in coil form direct to consumers; (13) use of very lightly coated electrolytic plate (0·2 lb.) instead of blackplate (thus eliminating finger marking and rusting, and also facilitating soldering); (14) production and use of differential coatings on electrolytic tinplate, whereby a heavier coating of tin is deposited on one side, or with tin coating on one side only, with a consequent saving of tin; and (15) effect of atomic energy.

It should be remembered that, as tin had always been a most expensive commodity, it had been the aim to cover plates with as thin a coating as possible, and yet to produce a smooth and non-porous surface. To obtain such a surface the tinning operation and tinning machinery had gradually been perfected, as was shown by the weight of tin coatings recorded over the past years:

Year	Weight per basis box, lb.*	Year	Weight per basis box, lb.*
1755	14	1930	2¼
1820	10	1942	1¼
1857	9	1946	1
1874	4¼	1952	¼ (electrolytic)

* One basis box is 112 sheets of 20 in. × 14 in. (31,360 superficial inches), weighing 108 lb.

There were signs that the tinplate industry would, in the future, be faced with competition from substitute materials, such as glass, cardboard, aluminium, and aluminium-coated steel, in fields where tinplate had, so far, been supreme. Nevertheless, the future tinplate manufacturers would be aware of such competition, and he was confident that, being of the same calibre as their ancestors, they would make such progress as would enable them to meet and overcome it.

B.T.H. Research in 1951

IN a review of the activities of the B.T.H. Research Laboratory* during 1951, Mr. L. J. Davies, Director of Research, draws attention to a number of interesting developments. The many different end products of a large electrical engineering concern, and the wide range of materials used in their manufacture are reflected in the many diverse problems which were under investigation in the year in question, but exigencies of space limit our references to a few examples of metallurgical interest.

Materials Research

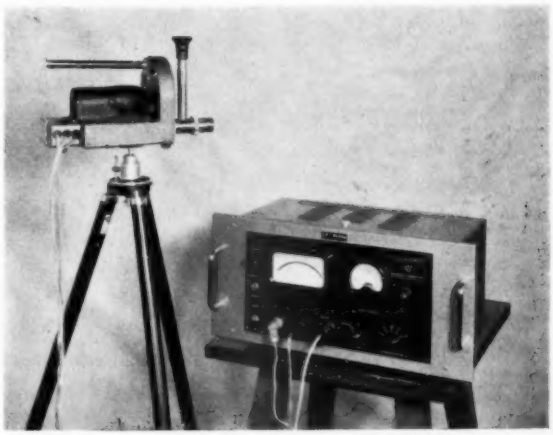
High Temperature Materials.—The creep properties of alloys for steam turbines and gas turbines is a subject of special interest and study, and a new apparatus has been made so that the accurate measurement of tensile creep can be carried out on a specimen much smaller than usual. This is of value when the material available for the test is limited in amount or dimension, the total volume used for the test being a cylinder 2 in. in length and $\frac{3}{8}$ in. in diameter.

Investigation has continued on the stress relaxation testing of bolt materials for steam turbines, interest being concentrated on the ferritic creep-resisting alloys, including a new stainless steel. This work was carried out to supply data for a special high-temperature high-pressure steam turbine with a maximum steam inlet temperature of 565° C. Work has also been in hand on the aspect of very long-time metallurgical stability of austenitic wrought alloys and weld metals at high temperature. The mechanical properties of these materials will be investigated after holding unstressed at 650°–660° C. for periods up to 10,000 hours.

Further progress has been made in the development of satisfactory welding techniques for gas turbine rotor forgings, the work having been extended to include much larger diameter forgings.

Prior to 1951 samples of bonded borides, carbides and oxides were prepared in a laboratory induction furnace and materials of this type are being studied extensively because of their possible applications to gas turbines. During the last year, special attention has been paid to the study of high melting point silicides and possible methods of bonding them to produce materials with high strength and good resistance to oxidation. The only successful bonding metal so far found for molybdenum disilicide is silver.† Compacts so made have higher bending strength than any metal bonded oxide so far known, and the oxidation resistance of the compact is much superior to that of bonded carbides. Work is continuing on other silicides and bonds of higher melting point.

Magnetic Sheet Steel.—Effort in this field has been largely concentrated on the properties of samples of cold reduced silicon iron as obtained from various sources. The results so far indicate that although the final annealing atmosphere (whether pure dry hydrogen, pure dry nitrogen, or mixtures of the two) does not necessarily affect markedly the total watts loss in material as received, some annealing atmospheres may increase the "ageing" of the material, i.e. the increase in losses during life.



Infra-red radiation pyrometer.

Machining Research.—During the year the equipping has commenced of a machining research laboratory, where problems concerned with machining, with the machinability of materials, and with surface finish, etc., will be studied. To date, attention has been centred on the problem of milling Nimonic 80 alloy: the work has been mainly concerned with the clearance angle and its effect on the rate of wear and the finish imparted to the milled surface by the cutter.

An investigation is being made into methods of assessing the surface texture of machined surfaces that cannot be presented to the probe of a surface measuring machine; two methods are being tried, the first a technique giving a solid resin casting, and the second a pliable film technique.

Apparatus Research

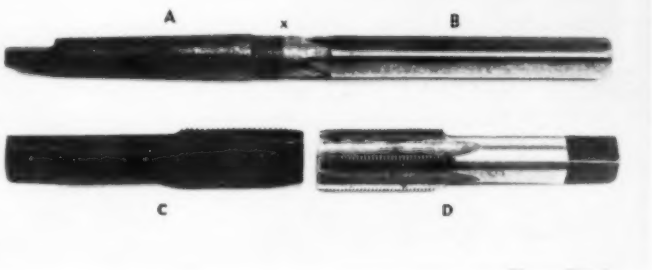
Infra-Red Radiation Pyrometer.—Work on the applications of lead sulphide photocells has resulted in the development of a radiation pyrometer measuring surface temperatures down to 150° C. This functions as a photoelectric flicker-photometer in which the intensity of radiation received from the surface under test is compared with that from a lamp housed in the instrument. A rotating sector disc cuts off the one and substitutes the other 1,000 times per second; the input to the lamp is adjusted until an amplifier tuned to this frequency indicates no A.C. output from the cell. When this occurs, the two radiations are of equal intensity and the lamp input then measures the temperature of the source according to a previously calibrated scale. Alternatively, the comparison lamp may be used to calibrate the instrument as a direct deflection pyrometer, for use in conditions where the source temperature is rapidly varying. The area of source is 5 × 1 mm. at 15 cm. from the pyrometer, or more at greater distances, for the range 150°–500° C. Higher temperature ranges may be covered with smaller source

* To be published shortly in *B.T.H. Activities.*
† Patent Application 357/52.

areas or by the use of filters. It is clear that the uses of this instrument are likely to be widespread wherever the temperature of inaccessible objects has to be measured, and particularly where the temperatures of such objects are too low (say, below 700° C.) for the use of an optical pyrometer.

Infra-Red Photoelectric Relays.—Experiments in conjunction with life tests on cells at high currents, have shown that lead sulphide photocells are capable of directly controlling powers considerably above the capacity of other types of photocell. Thus, a lead sulphide cell can close and open the contacts of a suitable relay in response to irradiation without the interposition of a valve amplifier; and as the system can work direct from A.C. mains a transformer (also necessary in a standard photoelectric relay) is not required. However, a more intense radiation is necessary. The more important feature of a lead sulphide photoelectric relay is that it can respond to heat radiation from low-temperature sources. By the use of a multi-stage amplifier, a relay equipment responsive to a source at only 100° C. has been developed, and work is in progress to detect hot axleboxes on railway trains by a cell mounted at the track side.

Sorting Tungsten Steel From Carbon Steel Scrap



As a result of the shortage of tungsten it has become important to reclaim, as salvage, worn and broken high-speed steel tools, because of the tungsten they contain. The Ministry of Supply has a schedule of controlled prices for solid scrap, depending on the alloy content of the steel. These scrap prices range from about one halfpenny per lb. for carbon steel to 7s. 6d. per lb. for steel of high tungsten content.

Many tools are made up of carbon steel shanks and tungsten steel cutting portions welded together. Others are made wholly of the former material—or of the latter. It is difficult to distinguish the more from the less valuable scrap material, using cheap testing methods so as to maintain the large difference in value of the materials. Many effective methods, such as the determination of magnetic or chemical properties or of specific gravity, are also costly. This article describes a simple but effective system which was proposed by Mr. A. M. Armour of the Research Department of Metropolitan-Vickers Electrical Co., Ltd., and is used by that Company, in conjunction with grinding spark tests, to sort high-speed steel from carbon steel.

It is well known that high chromium-bearing steels are very resistant to rusting. It is not generally realised, however, that the 10–30% tungsten steel alloys are also to a large extent, resistant to rusting. The fact that this resistance is markedly superior to that of carbon steel can be made to furnish a very easily recognisable distinction between these two latter alloys.

The illustration shows a carbon steel taper shank A welded to a tungsten steel reamer B. It also shows a carbon steel tap C and a high-speed steel tap D. These tools had been lying about the workshop for several weeks, so being acted on by the normal atmosphere. It is obvious that the parts A and C have suffered much more rusting than parts B and D, and this fact, once pointed out, can be appreciated without any aptitude beyond normal perception.

Such a process of rusting is lengthy, but it can be markedly accelerated by cleaning a small part of the surface with emery wheel or cloth, then wetting this with a strong solution of ammonium chloride (sal-ammoniac) in water, and leaving it in the air while still wet. In about 15 minutes the carbon steel turns golden brown with rust, whilst the high-speed steel remains more or less free from rust, depending on the alloy. In the photograph the line of material change at the weld X on the parallel portion of the reamer can be seen by the change in the rusting properties overnight after this treatment. With practice in the use of the method, the degree of discrimination amongst alloys improves.

This extremely simple and cheap test has been described so as to enable all who need to discriminate between high carbon steel and high-speed steel to use it. Thus the sorting of tool steel scrap will be helped, and the tungsten-bearing material salvaged for future use to the benefit of the country's imports.

The reclamation of tungsten from tool tips or from grinding swarf and the like is not such an economic proposition.

Aluminium Development Association
New President Elected

At the annual general meeting of The Aluminium Development Association last month, Mr. H. G. Herrington, was elected President for the year 1952–53. Mr. Herrington is Managing Director of High Duty Alloys, Ltd., Slough, and a Director of the Aluminium Wire and Cable Co., Ltd., Port Tennant, Swansea. He served as Chairman of the Executive Committee of the Association until 1949. The new Vice-President is Mr. R. D. Hamer, a Vice-President and Director of Aluminium Laboratories, Ltd. Mr. G. W. Lacey, Sales Director of the British Aluminium Co., Ltd., was elected Chairman of the Executive Committee of the Association.

At the meeting the retiring President, Mr. Austyn Reynolds, introduced the annual report of the Association and stressed the long term investigations which were in progress on new applications in shipbuilding, transport, building and structural engineering. They were being continued at high priority in order that full technical information should be available to users.

Pickling, Phosphating and Priming of Structural Steel

Appleby-Frodingham Development

NUMEROUS estimates have been made of the losses incurred due to the corrosion of steel. In 1940, for instance, it was estimated that 800 million tons had been lost in the preceding 50 years, or about 40% of the total world production of pig iron during the same period. Of even more moment are the estimated annual sums spent in an attempt to combat these terrific losses, and in the United States alone it has been estimated that more than 500 million dollars per year are spent on raw materials used to provide protective coatings, apart from the labour costs involved in their application. The methods of protection are constantly under review, and it is agreed that the best results would be obtained by the application of a specific treatment on completion of the fabrication and erection of the steel structure. Physical difficulties and the enormous cost of such processes preclude this. It follows, therefore, that any effective protection which can be given must, of necessity, be done item by item. It is somewhat of a new departure in this country for the steelmaker to undertake this work, but the Appleby-Frodingham Steel Company has installed plant to meet the growing demand for steel which has been pickled, phosphated and primed.

Normal corrosion troubles on steel surfaces have their origin in the millscale and rust which are integral parts of the steel as supplied, unless some special treatment is carried out after the steel leaves the mills. Were it possible to paint over an unbroken film of millscale, satisfactory protection could perhaps be achieved, but the millscale film, due to cooling, flattening, straightening, and general steelworks handling is never intact. Moisture in contact with the steel and broken millscale film produces rust, and in the process of rust formation swelling occurs. The swelling is progressive, and once started bursts off the adherent millscale in its vicinity together with any paint or other protective coating. This corrosive process, therefore, gathers momentum, and continues at an ever increasing rate as protective films are progressively destroyed and more and more steel is exposed to the atmosphere. Further, the process may be accelerated by the contamination of the atmosphere with industrial fumes. It is logical, therefore, to remove the millscale and start protective measures on completely clean steel.

The Plant

The process adopted in Appleby-Frodingham's new plant is the Footner Process, the complete cycle of operations of which is as follows :—

(*a*) Immersion in 5% sulphuric acid at 65° C. for 15–25 minutes.
(*b*) After draining two dips in water at 60°–65° C.
(*c*) Immersion for 3–5 minutes in a solution containing 2% free phosphoric acid and 0·3%–0·5% iron at 85° C.
(*d*) Priming while still warm.

The immersion in phosphoric acid produces an adherent coat of iron phosphate, which is rust inhibiting (not rust preventing) and is an excellent key for paint. The fact that the steel is primed while still warm assists drying and prevents any condensation of moisture on its surface. It will, of course, be realised that it is useless to pickle and phosphate unless this is followed by priming.

The plant recently installed is housed in a 160 ft. extension to the original Stainless Steel Pickling Plant. There are three vats, each 40 ft. long by 5 ft. wide by 9 ft. 6 in. deep, which contain the sulphuric and phosphoric acids, and water respectively. These are served by a 10 ton E.O.T. crane which carries specially designed cradles and beams to deal with the plates or sections to be pickled. Priming is carried out by brushing, which ensures a good bond between the phosphated surface and the paint. To economise in floor space, large plates are painted while standing on edge and leaning against specially placed stanchions. Contact is avoided between the painted surfaces by the introduction of small steel separators. Smaller plates and sections are painted on benches specially designed for the purpose. It will be appreciated that the maximum sizes which can be handled are of the order of 38 ft. long by 7 ft. wide for plates and 38 ft. long for sections.

Advantages of the Treatment

There are two distinct advantages to be claimed for this form of protection to be undertaken by the steelmaker, viz. :—

(*a*) The steel leaves the steelworks fundamentally clean, i.e., free from millscale, and contained in an envelope of paint. Apart from minor damage

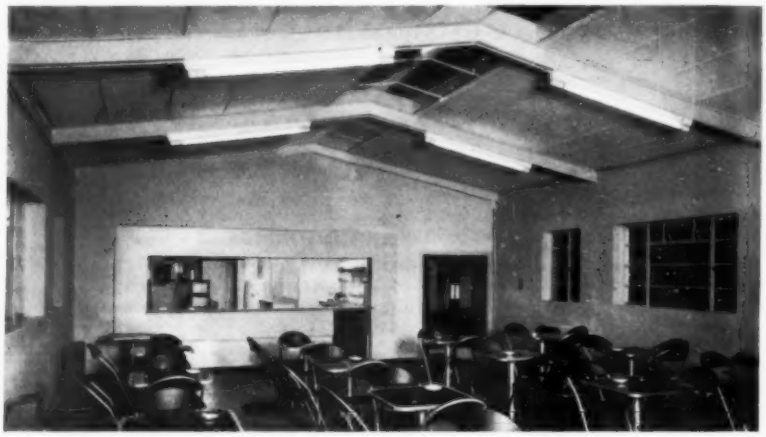
which will occur due to handling, it will remain clean and protected (within reasonable limits) until required for fabrication.

(*b*) When the fabricator uses the steel, the bulk of the priming has been done for him and he only requires to re-clean and re-prime such areas as he has damaged during his fabricating processes.

The application of steel, protected by pickling, phosphating and painting in the sphere of the engineer, lies in exposed steel structures. It is designed simply to provide a clean surface on to which a series of coats of paint can be applied as the final form of protection. It follows, therefore, that over a period of years, after a structure has been erected, the maintenance costs should be reduced, because the expense of cleaning down by, say wire brushing, or flame cleaning is substantially avoided and the intervals between re-paints extended. Tests carried out by a number of research bodies, notably the Corrosion Committee of the British Iron and Steel Research Association have proved beyond doubt the advantages of this method of surface preparation in the campaign against the corrosion of mild steel.

1. The Effects of Different Methods of Pretreating Iron & Steel before Painting. Iron & Steel Institute Special Report No. 31. G. F. Fancutt (1946).
2. Service Trials of Painting Schemes applied to a Steelworks Gantry. J. C. Hudson. Journal of the Iron and Steel Institute, Vol. 159, p. 60 (1948).

Aluminium in Building



Interior view of the Fulmer Research Institute Staff Canteen.

THE post-war years have seen considerable advances made in the application of aluminium and its alloys in various fields, particularly in structural engineering and building, where extensive use is now made of sheet and section material. The examples described below serve to illustrate this point, comprising as they do a research institute canteen with light alloy structural members, and a primary school with a roof covering of Super Purity aluminium.

Research Institute Canteen

The canteen for the Fulmer Research Institute is planned for the use of the employees at the present laboratories on a self-service basis at one sitting, whilst allowing for adaptation to two sittings when the complete project for new laboratories has been completed. The building will also provide social and lecture room facilities, and the disposition of the canteen and amenities has been planned to allow for this dual function.

The complete project comprises a series of standardised single-storey buildings, each a self-contained specialist laboratory and each connected to a two-storey general laboratory and administrative block: this new canteen comprises the first bay. As the use of these laboratories may be varied, complete flexibility is required. Any one or more of the various laboratories can be built as the second or third stage development, and length variations or extensions can be built in multiples of 9 ft. A 3 ft. module in both directions was adopted to suit a standardised partition panel and unit fitments which would all be interchangeable.

The structure is an S.M.D. "Alframe" building, with portal frames at 9 ft. centres. These portal frames are of aluminium alloy extruded hollow box-section 6 in. × 3 in., the rafters being exposed below the low pitch roof. The cavity walls comprise a brick outer skin with 3 in. inner leaf of lightweight insulation blocks with a conductivity "U" of 0·21 B.T.U.s/sq. ft./°F/Hr.

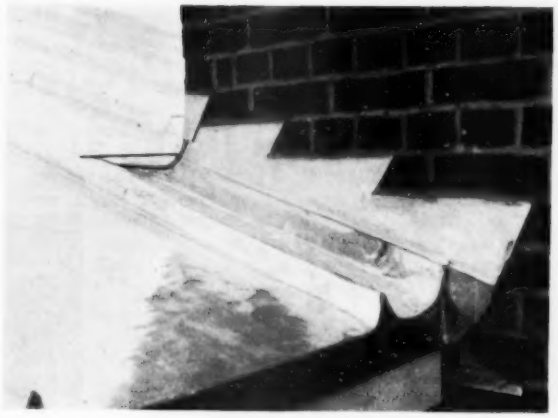
The roof consists of 2 in. "Stramit" boards supported on aluminium tee-section purlins and surfaced with bituminous built-up roofing, with roof light of curved Perspex sheets. The metal windows have pre-cast concrete surrounds.

The internal decoration is bright and cheerful, the walls generally being distempered dove grey with reflective areas yellow, while the doors are painted maroon and the rafters pale blue. Sills and surround to the servery are in pale blue mottled tiles.

Super Purity Aluminium Roofing

Using almost two tons of 22 s.w.g. Super Purity aluminium, and covering a total area of some 7,500 sq. ft., the roofing of the new Primary School at Kingsworthy, Winchester, is the largest installation of its kind, and demonstrates admirably how well this material responds to skilled craftsmanship.

General view of the 22 s.w.g. Super Purity aluminium roof covering of the Kingsworthy Primary School, Winchester, showing staggering of cross welts.



View showing string flashing and finish to back gutter.

The conical roll method of jointing was specified by the County architect, and the fixing contractors found that Super Purity aluminium was well suited to the standard hard metal roofing technique employed. This new flashing metal, which craftsmen plumbers are now using in the traditional manner, is shown to advantage in this instance as a high quality material for the specialist roofing firm.

The sheeting of the two roofs is laid on wood wool slabs with an underlay of inodorous felt. The roof of the assembly hall is the more interesting, showing as it does the single lock welt joint between overcloak and undercloak dressed down one side of the conical batten roll. The junction of the batten roll with the ridge roll is of particular interest, as also are the back gutter and stepped flashings to the large chimney stack on the north side. The lean-to roof of the classroom block shows the conical roll used with a capping piece, a method common in the United States, but only occasionally seen in this country.

Although Super Purity aluminium was first used in roof work only as recently as 1948, some indication of the long life to be expected from it may be obtained from the behaviour of one of the oldest roof installations of commercial purity aluminium to be found in Britain. Flashings to patent glazing were fixed to the roof of a Glasgow cooperage in 1927, and to-day, after 25 years' exposure to what is undoubtedly a most severe industrial atmosphere, they are still in excellent condition.

On technical grounds alone, therefore, it is clear that Super-Purity aluminium can more than hold its own in competition with more traditional metals. It is also an economical metal to use, labour costs being, if anything, lower than those for other metals, while the metal itself, at present day prices, costs less than comparable gauges in any other roofing metal.

Acknowledgments

The Architects for the canteen were A. F. Howe and Partners; the General Contractors, William Hartley & Sons; and the Sub-contractors, Structural and Mechanical Development Engineers, Ltd. (a member of the Almin group of companies), Thermalite, Ltd., Stramit Boards, Ltd., Granwood Flooring Co., Ltd., Carter & Co. Ltd., and North Thames Gas Board.

For the Kingsworthy Primary School, the Architect was the County Architect, Simpson Low, Esq.; the Main Contractor, H. N. Edwards, Esq., and the Roofing Contractors, Builders Iron and Zincwork, Ltd., The British Aluminium Co., Ltd., supplied the Super Purity aluminium sheet.

New Pipeline to Pump Nickel Ore Concentrate 7½ Miles

A 7½-MILE pipeline has been completed by The International Nickel Company of Canada, Ltd., through which the bulk concentrate from 3,650,000 tons of nickel-copper ore is being pumped annually from its newly built Creighton concentrator to its reduction plants at Copper Cliff. It is believed that never before has concentrate been carried by pipeline in such quantity over such a distance. The economies resulting from pipeline transportation, together with other economies, have made possible the working of lower-grade Creighton ore which is now contributing to the availability of nickel for the defence production needs of the free world.

Part of International Nickel's $130,000,000 programme of underground mine expansion, the pipeline artery has been integrated into an elaborate pipeline system which also carries tailing, or waste material, from both Creighton and Copper Cliff to a disposal area midway between the two plants. The system has 12 miles of trestle, at some points 65 ft. high to assure a slope to and from each of the five relay pumping stations so that the concentrate lines will be self-draining in case of power difficulties. All told, 3 million board feet of lumber and 40 miles of wooden pipe were used.

When milling 10,000 tons of nickel-copper ore a day at Creighton, approximately 1,800 tons of concentrate and 8,200 tons of tailing are produced. Water added to the concentrate makes a pulp which flows through the pipeline at a rate of 800 gallons per minute. The tailing pulp flows at the rate of 2,500 gallons per minute. Despite the rigorous northern winter weather, the complete pumping system has been designed for trouble-free operation. Several times the temperature has dropped to 30° below zero with no operating difficulties.

Welfare Projects at Thorncliffe

Foundry Baths and Works College Opened

ONE of the most comprehensive works colleges in industry was completed at the Thorncliffe Works of Newton Chambers & Co., Ltd., when, last month, the Minister of Labour and National Service, the Rt. Hon. Sir Walter Monckton, opened buildings providing new training accommodation for the Company's apprentices. The new buildings are situated in close proximity to the Business Training Centre for girls, erected in 1943 to provide training for replacements for office staff drafted into the Forces.

Apprentice Training

The Apprentice Training Centre, which from 1942 to 1952 occupied a number of adapted buildings within the Thorncliffe Works, now consists of a main central block and two wooden buildings around a quadrangle. The main building includes reception rooms, administrative offices, a gymnasium, a foundry training centre, laboratory, classrooms, and changing accommodation with shower baths. The wooden buildings include a number of classrooms, a machine shop, a constructional steelwork shop and a welding bay.

A section of the training facilities for apprentice engineers

Apprentices in the foundry have their own cupola for melting metal, their own mechanical sand-mixing, fettling, core-drying equipment, and their own sand-testing laboratory. Their small cupola, originally built by Thorncliffe constructional engineering apprentices, is installed in a special annexe. Other apprentices in the engineering shops work on machines which are painted in bright colours, and one does not have to look far to find proudly displayed examples of their work in metal. Bright colourful interiors and inspiring murals are a feature of the whole Centre.

The whole purpose and philosophy of Thorncliffe training is well summarised in the short extract from the epilogue (to the book "Thorncliffe") written by Sir Harold West (Managing Director)—"It is said by some that youth cares little for tradition or age or history and has little interest in what 'we have heard with our ears and our fathers have told us.' At any rate we at Thorncliffe have tried to make the first years of working life with us interesting and even exciting. In all this, of course, we have to observe with care the rules of employment, the procedure for negotiating wages and working conditions and the desirability of joint consultation between management and operatives, while reserving to management the responsibility for managing, a responsibility from which it must never shrink."

General view of clothes locker room in foundry baths

Foundry Baths

On the same occasion, Sir Walter opened the new baths which have been provided for the benefit of the Thorncliffe foundry workers. The main structure is 91 ft. long by about 50 ft. wide, and 11 ft. 6 in. high. On the north-east side is a tower containing on the ground floor the chlorifier chamber and on the first floor the Plenum chamber. Both

are big enough to allow the plant to be doubled.

The building has three main divisions: (1) The working-clothes locker-room; (2) the main bathing accommodation; (3) the clean-clothes locker-room. Main entrances and exits have ample sanitation and are equipped with mechanical revolving-brush boot-cleaning devices. Revolving doors seal off draughts and ensure effective heating, which is by the Plenum system. Air is drawn from outside, heated, conducted through the building, passed through the lockers, and exhausted into the main locker chambers. The heating system is augmented by radiators and a steam-heating coil is fitted to the main shower chambers.

The bathing chamber consists of four apartments fitted with showers and giving facilities for complete bathing. There is a separate chamber with standard wash-basins for the convenience of men who desire only hand-washing. All floors are hygienically tiled and the walls have been specially tiled in green and white. The ceilings are treated with granulated cork to reduce condensation, and exhaust fans cut down humidity.

Locker-chamber floors are of asphalt to give a warm, resilient and non-slip surface, with drainage channels for washing-down. The walls are tiled in green and side windows give plenty of light. Each man has two lockers, one for home clothes and one for working clothes. Lockers for 360 men are available, all of which have been taken up by workers in the foundries.

Mechanical Handling Exhibition

Iron, Steel and Foundry Exhibits

EFFICIENT handling of materials saves effort, time and money. It also promotes that flow of work which is of prime importance to high productivity; and of no industry is this more true than of the heavy engineering industry. To that industry, therefore, the appeal of the Third Mechanical Handling Exhibition and Convention, to be held at Olympia, London, from June 4th to 14th, 1952, will be particularly forcible.

There will be special portable short conveyors for handling forgings from presses; special pedestrian-controlled dumping trucks for movement of materials about the foundry or forge; pallets and trolleys for handling sheet steel; and overhead cranes, hoists and conveyors of many different types.

Various types of lifting magnets and magnetic separators for installation in conveyors, elevators, etc., will be shown, and there will be handling appliances for lifting and moving awkward articles direct from the floor, together with a complete range of press shop equipment. The range can be summarised as follows: precision slide feeds, built for accurate, fast and automatic feeding of coil strip to presses; stock straighteners (plain straighteners can be fitted to the slide feeds—power-operated models are self-contained units); stock reels and coil cradles.

There will also be seen a full-size working skip hoist of the semi-automatic type, in which, on pressing the control button, the skip hoist moves to its tipping position and automatically returns for refilling. Other features will include a sand handling unit for use in conjunction with moulding machines in foundries; a skip hoist for elevating and delivering bulk materials to a range of bunkers; and a portable lifting gantry complete with electric hoist, grips and tongs.

In addition, there will be a full size working wagon tippler; many types of mould conveyors; a new form of variable speed control for electric hoists; an actual 10-ton, 3-motor, heavy duty cage controlled overhead crane; radio control gear for cranes; and a power-driven coil up-ender to handle coils of aluminium sheet weighing up to two tons.

Convention Papers

During the Convention some twelve papers by leading specialists will be read. Among the speakers will be:—

MR. J. BAIN, Director of Paterson Hughes Engineering Co., Ltd., Glasgow and London;

MR. V. SADLER, Director of Vaughan Crane Co., Ltd., Manchester;

MR. J. H. HUNTLEY, Director of Sir William Arrol & Co., Ltd., Glasgow;

MR. T. ELKINGTON, Managing Director of Peter Brasshouse, Ltd., Birmingham;

COMMANDER A. C. HARDY, Chief Co-ordinator of the International Cargo Handling Co-ordination Association;

MR. K. B. WARWICK, General Manager, G. W. King, Ltd., Hitchin and Stevenage;

MR. B. POLLARD, Director of W. J. Jenkins, Ltd., Retford;

MR. L. LANDON GOODMAN of the British Electrical Development Association;

MR. L. RUMLEY, Sales Director of Conveyancer Fork Trucks, Ltd., Warrington;

MR. L. W. BAILEY, Consultant.

Separate tickets, without charge, are necessary for admission to the Convention. These can be obtained on the day the paper is to be read from the Convention ticket kiosk inside the Exhibition Hall. Visitors may advise the organisers ("Mechanical Handling," Associated Iliffe Press, Dorset House, Stamford Street, London, S.E.1) beforehand of the papers they wish to hear; tickets will then be reserved for them.

A.I.D. Approval for Etching Primer

THE one-component etching primer for non-ferrous metals and plastics, which was announced by Federated Paints, Ltd., of Glasgow, a year ago, has now been approved by the Aeronautical Inspection Directorate. Many manufacturers, users of non-ferrous metals, found that the new product eliminated waste caused by 'gelling' after mixing and gave better adhesion than the two solution primers, but aircraft manufacturers were unable to use the product pending completion of A.I.D. tests for approval under Specification D.T.D. 900. These tests have now been completed and Provisional Approval No. 4238 has been granted. At the same time, the Ministry of Supply has granted approval of Strathclyde etching primer under Specification No. C.S.2626. This is the first one-component primer to be granted approval under these specifications.

NEWS AND ANNOUNCEMENTS

The Institution of Mining and Metallurgy

The Gold Medal of the Institution has been awarded to DR. G. K. WILLIAMS, B.M.E., D.Eng., M.I.M.M., in recognition of the importance of his work in connection with research into the metallurgy of lead and zinc and the development of metallurgical processes.

Honorary Membership of the Institution has been conferred on Mr. E. HOOPER, Past President, in recognition of his services in the development of the Institution from its foundation sixty years ago, and on MR. E. D. MCDERMOTT, A.R.S.M., M.I.M.M., Past President, in recognition of his services to the Institution and to mining and metallurgical education.

'*The Consolidated Gold Fields of South Africa, Limited*' *Gold Medal* for 1951 has been awarded to MR. H. E. JEFFERY, A.C.S.M., A.M.I.M.M., for his paper, 'Notes on Fire Prevention and Fire-fighting, with Particular Reference to the Kolar Gold Field' (*Transactions*, vol. 60); and '*The Consolidated Gold Fields of South Africa, Limited*' *Premium of Forty Guineas* has been awarded conjointly to MR. R. CORNTHWAITE and MR. F. JURETIC, Affiliate I.M.M., for their paper on 'Sinking of Irwin Shaft at Roan Antelope Copper Mine' (*Transactions*, vol. 60).

The '*Arthur Claudet*' *Student's Prize* has been awarded to MR. T. A. A. QUARM, Student I.M.M., for his paper on 'A Method for the Preparation of High-purity Indium Metal' (*Transactions*, vol. 60); and the '*William Frecheville*' *Student's Prize* to MR. A. P. MILLMAN, A.R.S.M., B.Sc., A.M.I.M.M., for his part authorship of the paper on 'Heavy Metals in Vegetation as a Guide to Ore: A Biogeochemical Reconnaissance in West Africa' (*Transactions*, vol. 60).

Royal Society News

ONE of the four European scientists recently elected Foreign members of the Royal Society was M. A. M. Portevin, the eminent French metallurgist. M. Portevin is described in the citation as "distinguished for his outstanding contributions to the science of ferrous and non-ferrous metallurgy and their applications to industry."

The Council of the Royal Society has appointed Mr. E. M. Gunnersen, a graduate of Melbourne University, as the first Rutherford Scholar for three years from 1st October, 1952, to carry out work in nuclear physics at a university in the United Kingdom.

International Powder Metallurgical Seminar

DR. PAUL SCHWARZKOPF, President of the American Electro Metal Corporation, Yonkers, New York, and owner of the Metallwerk Plansee, Reutte, Tyrol, is inviting colleagues and friends of powder metallurgy to attend the First Plansee Seminar "De re metallica" which will take place from June 22nd to 26th, 1952, in Reutte.

The Seminar is under the auspices of the U.S. High Commissioner for Austria, Walter J. Donnelly; the Austrian Minister of Education, Dr. Ernest Kolb, the Rector of the University of Innsbruck, Dr. Eduard Reut Nicolussi; and a representative of the Tyrolean government. The tentative programme includes a lecture by the English scientists Dr. T. Raine and Dr. E. Edwards of Metro-Cutanit, Ltd., London, as well as lectures by the following American participants: Prof. G. J. Comstock, Prof. V. D. Frechette, Dr. H. H. Hausner, Dr. W. J. Kroll, Dr. J. T. Norton and Dr. J. Wulff.

Beilby Memorial Fund Awards

THE Administrators of the Sir George Beilby Memorial Fund, representing the Institute of Metals, the Royal Institute of Chemistry and the Society of Chemical Industry, have decided to make two awards, each of one hundred guineas, from the Fund for 1951. These awards have been made to:—

Kenneth Henderson Jack, M.Sc.(Dunelm), Ph.D.(Cantab), F.R.I.C. in recognition of his experimental contributions to the study of interstitial alloys, especially in the iron-nitrogen and iron-carbon-nitrogen systems.

William Arnold Wood, D.Sc.(Manchester), F.Inst.P., in recognition of his experimental contributions to knowledge of the mechanism of deformation of metals.

Awards from the Fund are made to British investigators in science as a mark of appreciation of distinguished work, particularly in such fields as fuel economy, chemical engineering and metallurgy in which Sir George Beilby's special interests lay. In general, the awards are not applicable to the more senior investigators but are granted as an encouragement to relatively young men who have done independent work of exceptional merit over a period of years.

English Electric Get U.S. Contract

THE English Electric Company has been awarded a contract by the U.S. Department of Interior's Bureau of Reclamation to construct a fourth large transformer for the Folsom Power Plant switchyard at the Central Valley Project in California. The contract is for an 80,000 kVA auto-transformer, which will be the first non-American equipment to go into this big hydro-electric project. Besides submitting the lowest tender, the English Electric Company was the only company stating that delivery would be made within the specified time of two years. The U.S. Department of Commerce noted that English Electric's progress on its new contract would no doubt be closely watched by many in the United States.

International Instrument Exhibition

THE tenth Anniversary of the Instrument Society of America will be celebrated by the holding of the first International Instrument Congress and Exposition in the Commercial Museum and Convention Hall, Philadelphia, from September 14th to 24th, 1954. At a meeting held recently, at which Dr. A. O. Beckman, President of the Society, was host to the Commercial

Counsellors of 12 Embassies, an invitation was extended to foreign manufacturers to exhibit at Philadelphia. It is expected that this meeting will attract a world-wide audience from manufacturing companies, research laboratories, educational institutions and government bureaux. Information on the Congress and Exposition can be obtained from Richard Rimbach, Managing Director, 921, Ridge Avenue, Pittsburgh 12, Pennsylvania, U.S.A.

Fifty Years of Manufacturing Celebrated at B.T.H. Rugby Works

FIFTY years of manufacturing at Rugby were celebrated by a Lunch in the B.T.H. Works Canteen on Friday, May 2nd. Mr. H. L. Satchell, M.B.E., Director, Manager B.T.H. Rugby Works, presided over the assembly of 230, which included Mr. James Johnson, M.P. for Rugby, the Mayor and Town Clerk of Rugby, the Secretary of the Engineering and Allied Employers' Leicester and District Association, a number of Trade Union Officials and some 200 employees of the British Thomson-Houston Company. Some of the latter had over 50 years' service with the Company, and many over 40 years.

Personal News

SIR WILFRID EADY, who recently retired from the Treasury, has been appointed a whole-time Director of RICHARD THOMAS & BALDWINS, LTD., and a Director of THE STEEL COMPANY OF WALES, LTD., with effect from June 1st.

MR. C. HERVEY, M.B.E., has succeeded, as Public Relations Officer of THE UNITED STEEL COMPANIES LTD., MR. E. T. SARA, who is now Commercial Research Manager.

MR. W. F. RANDALL, Director of THE TELEGRAPH CONSTRUCTION AND MAINTENANCE CO., LTD., will, at the invitation of the British Iron and Steel Research Association, act as Chairman of the newly-formed conjoint Committee of B.I.S.R.A. and the Electrical Research Association on Electrical Sheet.

MR. T. POWELL, Managing Director of BRITISH ELECTRO METALLURGICAL CO., LTD., left on May 14th for a visit to the United States to see a number of ferro-alloy plants.

MR. S. T. ROBSON resigned from the Boards of HEAD, WRIGHTSON & CO., LTD., and of HEAD, WRIGHTSON PROCESSES, LTD., at the end of last month.

As a result of certain organisational changes at the STEEL, PEECH & TOZER BRANCH OF THE UNITED STEEL COMPANIES, LTD., there will be two Works Managers responsible to the General Works Manager. They will be MR. H. R. BRUNYEE, Works Manager, Production Departments, and MR. G. N. F. WINGATE, Works Manager, Services Departments. The Superintendent, Rolling Mills, will be MR. P. WRIGHT, M.C., at present Assistant Works Manager (Heavy Departments), Samuel Fox & Co., Ltd., and MR. C. H. HAYTER, O.B.E., Cold Rolling Mill Manager, will be Superintendent of Ickles Departments. MR. J. LEES will be Cold Rolling Mill Manager and MR. C. S. WILKINSON will be Assistant Cold Rolling Mill Manager. The last two appointments are effective from May 5th, 1952, and the remainder from July 1st, 1952.

AT the end of last month, LT.-COL. K. G. MAXWELL, M.C., retired from executive duties as Manager of the Publicity Department of the METROPOLITAN-VICKERS ELECTRICAL CO., LTD. He is succeeded by MR. E. E. WALKER, who became Acting Manager in 1941 during the temporary absence of Colonel Maxwell, and on Colonel Maxwell's return in 1945 was appointed Assistant Manager. Colonel Maxwell will continue to be available to the Company in an advisory capacity.

PLATT BROS. (SALES), LTD., announce the appointment to their Board of MR. F. C. HAWKINGS, Home Sales Director and MR. E. C. MARLAND, Technical Director.

MR. R. G. DUCKETT, Technical Sales Manager of FOUNDRY SERVICES, LTD., of Birmingham, recently attended the International Foundry Congress at Atlantic City and is now with the technical personnel of FOUNDRY SERVICES (CANADA), LTD., visiting a number of foundries in various parts of Canada.

MR. G. R. BELL recently relinquished his position as Manager of the Metal Powders Plant, F. W. BERK & CO., LTD., of Stratford, to assume the position of Personal Technical Assistant to Dr. W. D. Jones in the Powder Metallurgy Division of POWDER METALLURGY, LTD.

JOHNSON & PHILLIPS, LTD., announce that their Engineer and Manager for Scotland, MR. G. GILLESPIE, retired from business at the end of last month. He is succeeded by MR. B. RUSSELL, who has had more than 30 years service with the Company and is now Manager of the Edinburgh Branch. The appointment is also announced of MR. R. L. STANLEY as Manager of the Glasgow Branch.

FOUNDRY SERVICES, LTD., announce that MR. W. D. CUTLER, who for the past two years has been one of their representatives in the Lancashire area, is moving early next month to Italy to become their resident technical representative there. His Lancashire territory will be taken over by MR. R. A. BLINCOE, of 9, Gainsborough Drive, Rochdale, Lancs.

MR. R. CAMPBELL WILLIAMS has resigned from NEW METALS & CHEMICALS, LTD., where he was technical manager for many years, and has started a private consulting practice at 16, Robins Court, Kings Avenue, London, S.W.4, specialising in the rarer metals and alloys which have been his particular interest for a number of years.

KEITH BLACKMAN, LTD., announce that MR. J. G. EMINTON, formerly of the London Head Office, is being transferred to Bristol to cover an area west of a line Banbury-Witney-Salisbury-Poole-Swanage, and enquiries from this area should be addressed to him at 13, West Dene, Westbury-on-Trym, Bristol, Glos. Telephone No.: Stoke Bishop 82519.

Obituary

WE regret to announce the deaths of the following:

MR. JOHN D. GEORGE, who died suddenly on April 16th, 1952 at the age of 25. Mr. George was a Director of W. & J. GEORGE & BECKER, LTD. and was the only son of the late Mr. W. J. George, one of the founders of the Company.

MR. ORLANDO G. R. BEERE, Director of the SELSON MACHINE TOOL CO., LTD. for the past 15 years, who died on April 7th, 1952, in his 75th year.

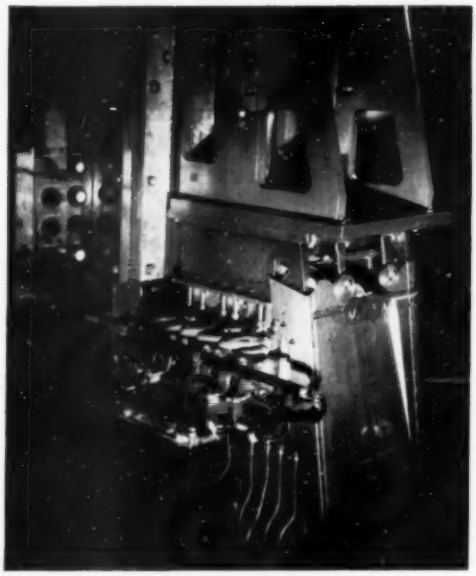
RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

A New Philips Multi-Point Welding Machine

An important new development in the resistance welding field is the unique machine for the high-speed automatic welding of motor-car bucket seats recently built by the Industrial Group of Philips Electrical, Ltd. This machine is one of the largest and most complex resistance welding equipments built in this country. Employing three operators, the Philips Multi-point Welder assembles nine different pressings requiring a total of 110 spot welds and one completed bucket seat is produced every 40 seconds. To equal this output, more than 14 operators using conventional spot-welding equipment would be required. Multi-point machines of this type can bring about a decrease of production costs of 56%.

The machine consists of three sub-stations mounted on a common base in the shape of a "T." The back panel and seat assembly, consisting of four sections, are assembled at the top right arm of the "T" and the base assembly of five sections at the top left arm. Both these sub-assemblies are passed to the operator at the third welding station (lower bar of the "T") where final assembly takes place. At all three stations the procedure is to load the assemblies on to self-contained copper-lined jigs and fixtures. These are part of the machine itself and locate the work pieces easily by means of runners, guides, slots and air-operated clamps. This brings about a considerable saving in loading time compared with that required for the manual clamping down and jigging of work on assembly jigs as used in gun welding.

At each station the work table with jig and assembly is raised pneumatically into welding position at a short distance from the electrodes. The table is then locked in order to withstand the cumulative pressure of the electrodes. After the automatic welding cycle it is returned to the loading position by exhausting the air cylinder.

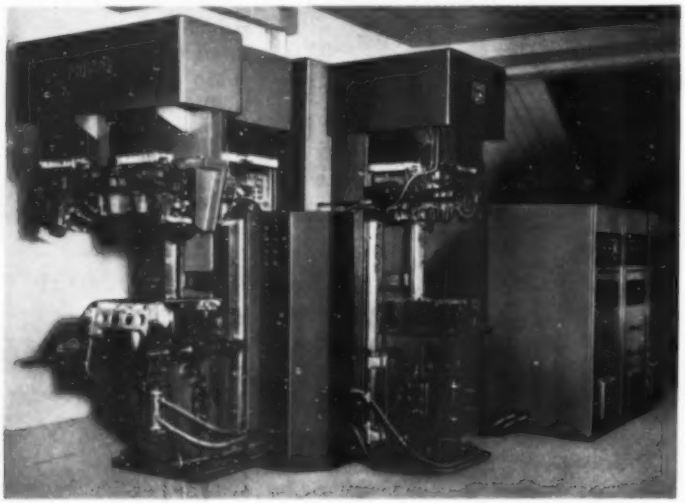


At this welding station final assembly of the seat takes place. The work table is here seen locked in the raised position, close to the welding head.

The electrodes, made of chromium copper for hardness and high conductivity, are hydraulically operated and individually water cooled. They descend upon the work piece in a quick succession of pairs, thus employing the series method of multi-point welding, the copper lining of the jig serving as current path. The maximum electrode pressure is 450 lb. at each welding point.

There are six electrodes attached to each welding transformer which is rated at 35 kVA. Employing respectively 4, 8 and 17 of these transformers, the three welding stations are interlocked to prevent their becoming synchronised and thus causing a high surge on the mains. The operator can keep his production rate in step by watching a small control panel attached to each station, which indicates the welding progress at the other stations.

The equipment for the automatic control of this complex system of electrical, hydraulic and pneumatic circuits, regulating the timing and interaction of the operations, consists of three separate cubicles mounted on a common platform each corresponding to one welding station. Contained within the control cubicles are the electronic programme timers which regulate each progressive stage of welding



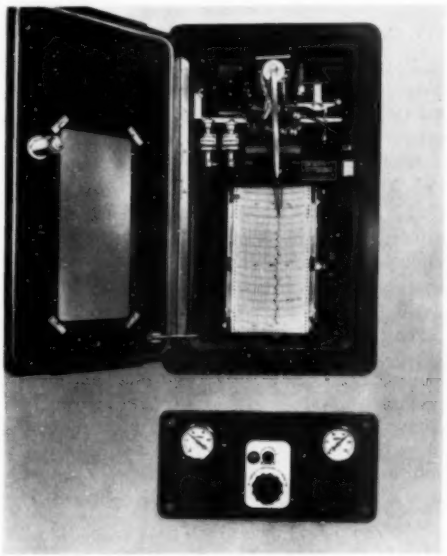
General view of the machine

and the speed of operation. A sequence timer ensures a correct welding cycle of pressure, weld and forge. This unit automatically resets itself when the work table is raised for welding.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

New Instrument for Controlling Gas Calorific Value

SINCE the recent war the load on gas-making plant has increased considerably, whereas gas-holder capacity in most works has not kept pace with this rise in demand. Because the gas is moving through the holder more rapidly, variations in calorific value are not smoothed out so effectively as previously. This necessitates a tighter control on the calorific value of the gas before it enters the holder.



To meet these needs, a new recording and controlling instrument for gas calorific value has been developed by the Sigma Instrument Company, Letchworth, and George Kent, Ltd., Luton and London. Known as the Sigma-Kent Controlling Calorimeter, the apparatus is being marketed by George Kent, Ltd.

The two basic parts of the controller are the new Sigma Mark 2 calorimeter and the Kent Mark 20 pneumatic control unit. The calorimeter is made up of a gas-flow regulator, measuring device and recording mechanism, the function of the regulator being to supply gas to the measuring device at a rate which would be constant if reduced to standard temperature and pressure (60° F. and 30 in. of mercury). The regulator also provides automatic compensation for changes in gas specific gravity and ambient temperature. The gas passes from the regulator to a burner in the measuring device. The burner is at the bottom of a vertical steel tube through which the products of combustion pass to atmosphere. This tube is contained within a second steel tube concentrically mounted, and the lower ends of both tubes are rigidly joined together, the upper end of the outer tube being fixed to the instrument case. A bar attached to the upper end of the inner tube transmits the relative expansion or contraction of the inner tube to the recording linkage. This relative movement is directly and immediately consequent on changes in the calorific value of the gas being burned. Ambient temperature changes have no effect on the apparatus because in this instance both tubes respond equally and no motion occurs at the upper end of the inner tube. The relative movement of the inner tube is magnified many times by the recording linkage, giving adequate motion to the pen of the recorder mechanism on the chart. In order to overcome slight zero errors sometimes associated with large changes in barometric pressure, there is fitted a combustion air compensating device which renders the calorimeter unaffected by barometer variations of over 4 in. of mercury.

The Kent control mechanism is fitted within the instrument case. A control setting pointer is mounted concentrically with the recorder pen, and the controller instantly detects, and takes action to correct, any deviation between the pen and the pointer. The deviation is converted into an air-pressure change within the controller system which moves a control valve in the diluent gas main to correct the calorific value of the gas. Proportional, integral and derivative functions of the controller ensure that the calorific value is returned to the control setting in the shortest possible time without overshoot in the opposite direction. The control valve usually employed is a butterfly valve operated by a power positioning cylinder.

George Kent, Ltd., Luton.

New Synthetic Resin Core-binder

AERO RESEARCH, LTD. have recently introduced a new form of " Resolite " synthetic resin core-binder. This product, marketed as " Resolite " 400 (patent applied for), is said to have overcome the difficulty of stickiness commonly associated with resin-bonded mixes and to facilitate core-making on the bench and in core-blowing machines. With " Resolite " 400, mixers can be run at a much greater capacity than with conventional urea-formaldehyde binders and it is claimed that drying out does not occur during normal periods on the bench. These advantages are obtained without affecting the rapid stoving times, good breakdown properties and other well-known characteristics of synthetic resin core-binders. Full details of " Resolite " 400 used in production processes are contained in *Aero Research Technical Notes* No. 112.

Aero Research, Ltd., Duxford, Cambridge.

Alumina Mortars and Pestles

A RECENT development of The Thermal Syndicate, Ltd. is the manufacture of mortars and pestles in their new Alumina Ware 609. The hardness of this recrystallised alumina (9 on Mohs scale) ensures that the new ware will not crack or craze during the grinding operation. Because of this extreme hardness, it is possible to grind hard and abrasive material without danger of contamination from the mortar or pestle. The new mortar is available in four different sizes and has an octagonal shape.

The Thermal Syndicate, Ltd., Wallsend, Northumberland.

CURRENT LITERATURE

Trade Publications

THE latest publication of the Northern Aluminium Co., Ltd., a 24-page booklet, "Properties of Noral Alloys," replaces the Noral Data Sheet which, in numerous editions, has achieved a wide circulation since its first appearance in 1945. Although the title implies exclusive reference to Noral products, its scope is actually very wide, for a quarter of its pages carry general notes on aluminium and its alloys, and practically all the rest of its contents relate to materials that conform to standard specifications. Seven tables show the properties of the principal Noral alloys in the forms in which they are supplied: sheet, plate, extrusions, tube, wire, forgings and castings. Quantitative values are expressed in figures, and qualitative by means of ratings, enabling designers to make a fairly precise assessment of each material.

WE have received from Mr. Jan. R. Dewidels, 6, Sandringham Gardens, Moortown, Leeds, United Kingdom agent for the high temperature furnaces of Gebr. Ruhstrat of Göttingen, a booklet describing this equipment. Based on a design of Professors Nernst and Tammann, these furnaces are the result of 30 years development. They are heated by means of the passage of a heavy electric current through a carbon tube, a transformer providing the low-voltage high-current supply required. One of the advantages of this type of furnace is that temperatures as high as 3,000° C. are readily and rapidly attainable, and whereas such furnaces were formerly used only for laboratory work, they are now finding application in sintering metal powders and melting metals and compounds of high melting point. They are available in a variety of forms, including a horizontal rectangular section muffle, and can be fitted with facilities for neutral gas, vacuum and pressure heating.

A COMPLETELY revised and up-to-date second edition of Publication No. 22, giving details of the Weldafume Unit, has recently been issued by Keith Blackman, Ltd. This new exhauster removes the heat, fumes and dust of welding operations from the vicinity of the operator, thereby contributing materially to his efficiency and the improvement of local conditions generally.

WE have received from Lees, Hall & Sons, Ltd., Newhaven, Sussex, a 36-page booklet detailing a variety of melting furnaces made by the Company. They include a number of tilting furnaces, lift-out crucible furnaces, bale-out and holding furnaces, etc., for oil, gas or solid fuel firing. Fixed and tilting reverberatory furnaces are also mentioned, together with cupolas, small heat-treatment furnaces, and enamelling, core drying and sundry gas-heated ovens. Reference is also made to a number of foundry accessories.

GAMMA-RAY radiography is now firmly established in industry as a non-destructive method of inspecting castings, welded assemblies and other engineering components. In the Johnson, Matthey Data Sheet 2783, which has recently been issued, information is given of an improved portable carrier, designed for use with sources up to a value of 500 millicuries of cobalt 60 or the equivalent. A time controlled exposure unit is also described which, when used in conjunction with the portable carrier, enables a large number of radiographs to be taken simultaneously. Exposures can be timed to take place in a cleared room at any convenient time of the day, or during the night.

Books Received

"Thermodynamics of Alloys," by Carl Wagner. Translated by Svante Mellgren and J. H. Westbrook. Fourth book in the Addison-Wesley Metallurgy Series. 161 pp. inc. indices and extensive bibliography. Cambridge, Mass., 1952. Addison-Wesley Press, Inc. $6·50.

"Welding of Non-Ferrous Metals" (Vol. III of "Welding Practice"). 183 pp. inc. glossary and index. London, 1952. Butterworths Scientific Publications in association with Imperial Chemical Industries, Ltd. 22s. 6d. net. Post 1s. extra.

"Steel Defects and Their Detection," by Henry Thompson, A.I.Prod.E., A.R.Ae.S., A.M.I.E.I. 84 pp. inc. bibliography, index and numerous illustrations. London, 1952. Sir Isaac Pitman & Sons, Ltd. 15s. net.

"Corrosion Testing Procedures," by F. A. Champion, Ph.D., A.R.C.S., F.I.M. 369 pp. inc. indices. London, 1952. Chapman & Hall. 36s. net.

"The Story of the Mushets," by the late Fred M. Osborn. Preface by Sir Samuel Osborn, LL.D., J.P. 195 pp. inc. appendices, bibliography, genealogical tables, index and illustrations. London, 1952. Thomas Nelson & Sons, Ltd. 21s. net.

"The Welding, Brazing and Soldering of Copper and its Alloys." C.D.A. Publication No. 47. 188 pp. inc. 81 illustrations, bibliography, appendices and index. 1952. Issued by the Copper Development Association. Free to those to whom it can be of service.

"A Guide to Filter Paper and Cellulose Powder Chromatography." Compiled by J. N. Balston, B.A., and B. E. Talbot. Edited by Tudor S. G. Jones, B.Sc., Ph.D., A.R.I.C. 145 pp. London and Maidstone, 1952. H. Reeve Angel & Co., Ltd., and W. & R. Balston, Ltd. 8s.

"The Heat Treatment and Annealing of Aluminium and its Alloys." Part I: Practice. Third Edition. Information Bulletin No. 3. 53 pp. inc. tables and selected bibliography. London, 1951. The Aluminium Development Association. 2s.

"A Bibliographical Survey of German and Japanese Experience in the Extraction of Low-Grade Non-Ferrous Ores and the Recovery of Non-Ferrous Metals and Compounds." Report No. RMS-3 of the Department of Scientific and Industrial Research, Technical Information and Documents Unit. 100 pp. inc. appendices. London, 1952. Her Majesty's Stationery Office. 3s. 6d. net.

"Guide to the Use of Aluminium in Public Service Vehicles." 27 pp. inc. appendices. London, 1952. The Aluminium Development Association. 2s. 6d.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

MAY, 1952 Vol. XLV, No. 271

An Absorptiometric Analytical Procedure of Particular Applicability to the Residues Which Result from the Chlorination of Steel

By S. Greenfield, L.I.M., and L. E. Sparrow
G.K.N. Group Research Laboratory

The development of an absorptiometric technique applicable to the analysis of oxide residues and designed to eliminate tedious gravimetric procedures is described. The evolved methods for the determination of silica, manganous oxide, ferrous oxide and alumina are given in detail, and the effect of other elements likely to be present in the residues is examined.

A COMMON method for the determination of oxide inclusions in steel consists of heating the steel in a current of dry oxygen-free chlorine. The metallic constituents and the non-oxide compounds are converted to chlorides which, being volatile at the temperature used, are removed in the gas stream, whilst a residue of oxides, slag, carbon and non-volatile chlorides remains. This residue, after filtration and suitable washing, is ignited. The analysis of the resultant oxides, which seldom weigh more than a few milligrams, necessitates the use of micro, or semi-micro techniques. Such methods, if gravimetric, are tedious and time consuming; they involve the use of a micro, or semi-micro balance, and the services of a skilled operator.

The oxides in the residue, which may safely be regarded as existing as lower oxides in the steel, are those of silicon, manganese, iron, aluminium and possibly titanium. Quite small amounts of each of these elements can be made to yield highly coloured solutions, whose light absorbing properties can be used to measure the concentration of the particular element. Advantage was taken of this fact to design a fairly rapid, accurate and straightforward analytical procedure obviating all use of the micro-balance; this procedure, used in conjunction with the "Spekker" absorptiometer can be applied to oxide residues by the normal routine staff.

Basis of Method

The first step in the development of the method was to obtain all the oxides in solution. The complex character of the oxides made them sparingly soluble, necessitating the use of a double fusion technique in which most of the residue was decomposed with sodium bisulphate, and the remaining silica with sodium carbonate.

The formation of silico-molybdate, with subsequent reduction to molybdenum blue, was an obvious choice for determining the silica content of the prepared solution. Work centred on finding a suitable reducing agent, and finally a method[1] was developed, in which oxalic acid and ferrous ammonium sulphate were used to reduce the silico-molybdate. The molybdenum blue obeyed Beer's law, but the presence of a background absorption due to the iron content of the solution made it impracticable to measure the absorption of this solution against that of the "blank" estimation; the method of compensation had to be adopted for both the prepared solution and the "blank."

In the case of manganous oxide, again the choice of method was fairly obvious—the formation of permanganate. Work again centred on finding a suitable reagent, in this case an oxidising agent. The stability of permanganate solutions formed by the use of potassium periodate, and the simplicity with which this reagent can be used, decided in its favour. Iron background was suppressed by the use of phosphoric acid, and interference from other elements was not detected with the filters used. The permanganate solution obeyed Beer's law and its absorption was measured directly against that of the "blank."

Before iron and aluminium could be estimated, it was necessary to separate them from other elements which might be present and would interfere with subsequent operations. Ammonium hydroxide was used for this separation. In preliminary experiments, the iron was separated from the aluminium with cupferron and chloroform.[2] The iron content of the chloroform extract was estimated absorptiometrically using thioglycollic acid. The excess cupferron in the aqueous extract from the iron separation was destroyed with perchloric acid and the aluminium precipitated with 8-hydroxyquinoline. This aluminium complex was extracted with chloroform[3,4] and its absorption measured. Although this method yielded accurate results, it was slow and tedious—features which it was desired to avoid. It was therefore abandoned in favour of a neat, accurate and

1. Gentry, C. H. R., and Sherrington, L. G., *J.S.C.I.*, March, 1946, 90.
2. Berman, Chap and Taylor, *Journal of the Assoc. of Official Agricultural Chemists*, 1937, **20**, 635.
3. Wiberley, S. E., and Basset, L. G., *Anal. Chem.*, May, 1949, **21** (5), 609–612.
4. Gentry, C. H. R., and Sherrington, L. G., *Analyst*, 1946, **71**, 432–438.

rapid method[5] using the reagent ferron to estimate both the iron and the aluminium in the same solution. The aluminium-ferron complex has a maximum absorption at 370 mμ and at this wavelength using small concentrations of aluminium at a constant *p*H, the complex obeys Beer's law. The iron complex is also absorbed at this wavelength, but the amount of absorption due to the iron complex can be accurately determined. At a wavelength of about 600 mμ, only the coloured complex of iron shows absorption. Thus both iron and aluminium may be estimated on the same sample.

Preparation of Basic Solution

A " blank " estimation using the specified quantities of reagents, filter papers, etc., must be carried through all stages of the method in parallel with the actual test.

Char the filter paper and contained residue in a platinum capsule at a low temperature until all carbonaceous matter has been destroyed, then raise the temperature to 1,000° C. and maintain for 10 minutes. Allow to cool, and mix the ignited residue intimately with 0·5 g. of sodium bisulphate. Fuse and maintain the melt at a low temperature until fusion is complete. Extract the cooled melt in a minimum quantity of water, filter through a Green's 803, 5·5 cm. filter paper into a 100 ml. flask, washing the residue with a small quantity of water. Ignite the residue in a platinum crucible, mix intimately with 0·5 g. of sodium carbonate (anhydrous), fuse, and maintain at a high temperature until fusion is complete.

Extract the cooled melt in 60 ml. of 14% sulphuric acid, add to the solution in the flask, and dilute to 100 ml. at 20° C. Take fractions from this prepared solution to estimate the individual elements.

PROCEDURE FOR INDIVIDUAL ELEMENTS

I.—SILICA

Reagents Required

Potassium Permanganate (2%)—Dissolve 2 g. of potassium permanganate crystals in cold water and dilute to 100 ml.

Hydrogen Peroxide (2 *vols.*)—Dilute 10 ml. of hydrogen peroxide (20 vols.) to 100 ml.

Ammonium Molybdate (5%)—Dissolve 5 g. of ammonium molybdate crystals in water and dilute to 100 ml.

Ferrous Ammonium Sulphate (2%)—Dissolve 2 g. of ferrous ammonium sulphate crystals in 50 ml. of water containing 1 ml. of dilute sulphuric acid (1 : 9) and dilute to 100 ml.

Oxalic Acid (2%)—Dissolve 2 g. of oxalic acid crystals in 50 ml. of warm water, dilute to 100 ml. and cool.

Procedure

Take a 20 ml. fraction of the prepared solution, heat to boiling and oxidise with dropwise additions of potassium permanganate solution (2%) until a permanent precipitate is obtained on continued boiling. Add hydrogen peroxide (2 vols.) until the precipitate is just discharged. Bring to the boil and cool. Dilute to 50 ml. in a graduated flask and mix thoroughly. Pipette two 10 ml. fractions into 50 ml. graduated flasks and treat as follows :—

(*a*) *Test Solution.*—Add 10 ml. of ammonium molybdate solution (5%) mix, and allow to stand for twenty minutes at 20 ± 2° C. Add 20 ml. of oxalic acid solution (2%), mix and allow to stand for five minutes. Add 5 ml. of ferrous ammonium sulphate solution (2%), dilute to 50 ml. and mix thoroughly.

(*b*) *Compensating Solution.*—Add 20 ml. of oxalic acid solution (2%) followed by 10 ml. of ammonium molybdate solution (5%) and 5 ml. of ferrous ammonium sulphate solution (2%), *mixing after each addition*, dilute to 50 ml. and mix thoroughly.

Obtain the difference reading between the absorption of the test solution and that of the compensating solution, using 4 cm. cells, the mercury vapour lamp and Ilford Yellow 606 filters, together with H.503 filters.

Relate the figure obtained for the test, after subtracting that obtained for the " blank " to a calibration graph prepared under similar conditions (Fig. 1).

Calibration

Solutions Required

Primary Silicate Solution. Weigh into a platinum dish 1 g. of pure silica, (previously ignited at 1,000° C.) fuse with 5 g. of anhydrous sodium carbonate and extract with warm water. Filter into a 1,000 ml. graduated flask, washing with 1% sodium carbonate solution, dilute to the mark and mix thoroughly.

Dilute Silicate Solution. Dilute 20 ml. of the above solution to 500 ml.

The silica content of the primary silicate solution is checked gravimetrically.

Procedure

Base Solution. Treat 70 ml. of sulphuric acid (1 : 9) and 25 ml. of water with potassium permanganate and hydrogen peroxide solutions exactly as described previously, and dilute to 250 ml. in a graduated flask.

(*a*) *Calibration Test Solutions.*—Pipette five 10 ml. fractions from the foregoing base solution and add 0–4 ml. of dilute silicate solution. Treat these solutions for colour development as described in the procedure for the determination of silica.

(*b*) *Compensating Solutions.*—Pipette a further five 10 ml. fractions from the base solution and treat as described for the compensating solution in the procedure for the determination of silica.

Using 4 cm. cells, the mercury vapour lamp and Ilford Yellow 606 and H. 503 filters, obtain difference readings between the colour solutions and the compensating solutions. Subtract the absorption due to the sample containing no silicate solution and plot the corrected differences against milligrams of silica.

II.—MANGANOUS OXIDE

Reagents Required

Phosphoric-Sulphuric Acid.—Add 260 ml. of sulphuric acid (S.G. 1·84) and 350 ml. of phosphoric acid (S.G. 1·75) cautiously to 300 ml. of water, cool, dilute to 1 litre.

Potassium Periodate (5%).—Dissolve 5 g. of potassium periodate in a mixture of 60 ml. of water and 20 ml. of nitric acid (S.G. 1·42) cool, and dilute to 100 ml.

Procedure

Take a 20 ml. fraction of the prepared solution, add 15 ml. of phosphoric-sulphuric acid mixture, heat to boiling, oxidise by the dropwise addition of nitric acid (S.G. 1·42) and boil to expel nitrous fumes. Dilute to 65 ml. and add 10 ml. of nitric acid (S.G. 1·42). Boil gently for 2 minutes, add 10 ml. of potassium periodate solution (5%) continue to boil gently for seven minutes

5. Davenport, W. H. (Jnr.), *Anal. Chem.*, June, 1949, **21** (6), 710–711.

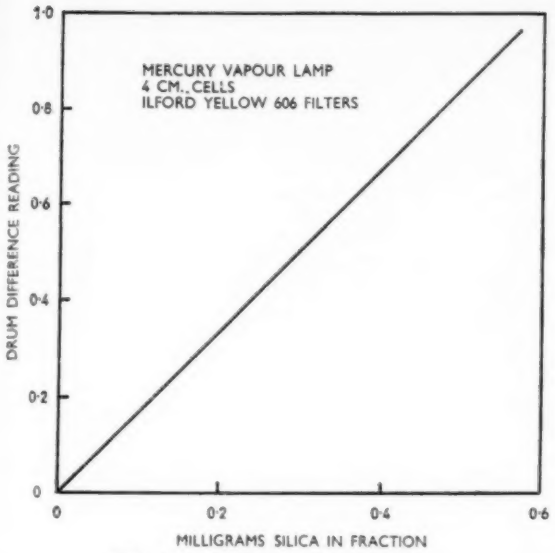


Fig. 1.—Silica calibration graph.

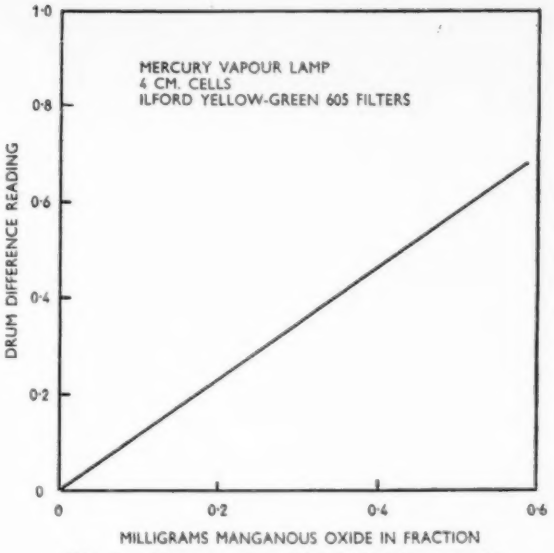


Fig. 2.—Manganous oxide calibration graph.

and allow to cool. Transfer to a 100 ml. graduated flask, adjust the temperature of the solution to 20° C., dilute to the mark and mix.

Obtain the difference reading between the absorption of the test solution and that of the " blank " using 4 cm. cells, the mercury vapour lamp, Ilford Yellow-Green 605 and H.503 filters. Relate the figure obtained to a calibration graph prepared under similar conditions (Fig. 2).

Calibration

Solutions Required

Primary Manganese Solution. Weigh out 2·228 g. of potassium permanganate crystals, dissolve in 100 ml. of hot water and boil gently for 15 minutes. Cool, filter through sintered glass into a 500 ml. graduated flask, dilute to the mark and mix.

Dilute Manganese Solution. Dilute 25 ml. of the primary manganese solution to 500 ml. in a graduated flask.

1 ml. ≡ 0·0001 g. MnO

The manganese content of the primary solution is checked by means of sodium oxalate.

Phosphoric-Sulphuric Acid. Add 150 ml. of sulphuric acid (S.G. 1·84) and 150 ml. of phosphoric acid (S.G. 1·75) cautiously to 600 ml. of water, cool and dilute to 1 litre.

Procedure

To ten 250 ml. conical beakers add 35 ml. of phosphoric-sulphuric acid mixture and known varying amounts of dilute manganese solution. Oxidise with nitric acid (S.G. 1·42) and proceed as described in the procedure for tests.

Obtain difference readings against the solution containing no manganese and plot against milligrams of manganous oxide.

III.—FERROUS OXIDE AND ALUMINA

Reagents Required

Ammonium Hydroxide (50%).—Dilute 50 ml. of ammonium hydroxide (S.G. 0·88) to 100 ml. with water.

Ammonium Nitrate (2%).—Dissolve 2 g. of ammonium nitrate in 50 ml. of water and dilute to 100 ml.

Hydrochloric Acid (50%).—Dilute 50 ml. of hydrochloric acid (S.G. 1·18) to 100 ml. with water.

Ammonium Acetate (40%).—Dissolve 40 g. of ammonium acetate in 80 ml. of water, and dilute to 100 ml.

Hydrochloric Acid (10%).—Dilute 10 ml. of hydrochloric acid (S.G. 1·18) to 100 ml. with water.

Nitric Acid (10%).—Dilute 10 ml. of nitric acid (S.G. 1·42) to 100 ml. with water.

Ferron (0·16%) (*8-hydroxy-7-iodo-5-quinoline sulphonic acid*).—Dissolve 0·4 g. of ferron in 200 ml. of water and dilute to 250 ml.

Procedure

From the prepared solution take a suitable fraction containing not more than 0·1 mg. of aluminium and a total concentration of iron and aluminium not exceeding 0·16 mg., add 2 g. of ammonium chloride and dilute to approximately 50 ml. Boil the solution and oxidise with four drops of nitric acid (S.G. 1·42). Carefully add ammonium hydroxide (50%) until a slight excess is obtained. Boil for two minutes, then filter through a 5·5 cm. Green's 803 paper and wash well with hot ammonium nitrate solution (2%). Dissolve the precipitate back into the original beaker with small amounts of hot hydrochloric acid (50%), finally washing the paper well with small portions of hot water. Add ammonium hydroxide (50%) dropwise until a small piece of added congo red paper just changes from blue to red. Cool, add, in the following order, 2 ml. of hydrochloric acid (10%), 2 ml. of nitric acid (10%), 10 ml. of ammonium acetate (40%) and 5 ml. of ferron (0·16%). Dilute to 50 ml. in a graduated flask and allow to stand for 15 minutes.

Obtain the difference reading between the absorption of the test solution and that of the " blank " using 2 cm. cells, the mercury vapour lamp, Ilford Yellow 606 and H.503 filters. Relate the figure obtained to a calibration graph for ferrous oxide prepared under similar conditions (Fig. 3 Curve A). Obtain a second difference reading

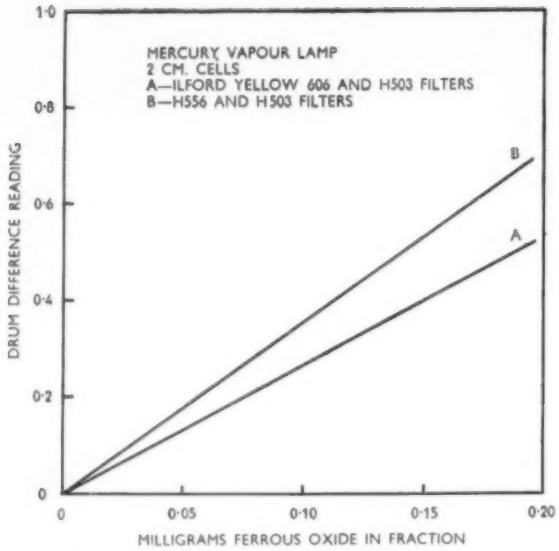


Fig. 3.—Ferrous oxide calibration graph and correction graph.

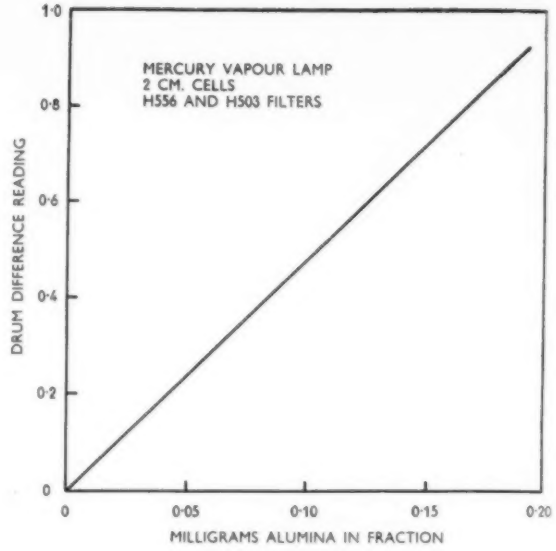


Fig. 4.—Alumina calibration graph.

between the two solutions using the mercury vapour lamp, H.556 and H.503 filters. From a correction graph constructed at this wavelength (Fig. 3 Curve B), obtain the contribution of the iron. Subtract this figure from the total reading, and relate to an alumina calibration graph (Fig. 4).

Calibration—Alumina

SOLUTIONS REQUIRED

Primary Aluminium Solution. Dissolve 0·3310 g. of pure aluminium in the minimum quantity of aqua regia, and evaporate to "moist dryness." Cool, and dilute to 500 ml. in a graduated flask.

Dilute Aluminium Solution. Dilute 20 ml. of the primary aluminium solution to 1 litre.

The aluminium content of the primary solution is checked gravimetrically.

PROCEDURE

Add 0–8 ml. of dilute aluminium solution to five 50 ml. graduated flasks. Add, in the following order, 2 ml. of hydrochloric acid (10%), 2 ml. of nitric acid (10%), 10 ml. of ammonium acetate (40%), and 5 ml. of ferron (0·16%). Dilute to the mark and allow to stand for 15 minutes. Obtain difference readings against the solution containing no aluminium using 2 cm. cells, the mercury vapour lamp and H.556 and H.503 filters. Plot the figures obtained against alumina content.

Calibration—Ferrous Oxide

SOLUTIONS REQUIRED

Primary Iron Solution. Dissolve 0·4858 g. of pure iron in 250 ml. of hydrochloric acid (5%) and dilute to 500 ml.

Dilute Iron Solution. Dilute 10 ml. of the primary iron solution to 1 litre.

The iron content of the primary solution is checked gravimetrically.

PROCEDURE

Add 0–14 ml. of dilute iron solution to five 50 ml. graduated flasks and proceed as for the alumina calibration. The figures obtained, plotted against milligrams of ferrous oxide, give the correction graph for iron at this wavelength.

Obtain further readings using 3 cm. cells, the mercury vapour lamp, and Ilford Yellow 606 and H.506 filters. Plot the figures obtained against ferrous oxide content.

Titanium, if present, forms a complex with ferron. This complex does not absorb at 600 mμ and therefore does not interfere with the estimation of iron. However, at 370 mμ there is some absorption. If the titanium dioxide content of the residue does not exceed 0·1 mg. the interference is negligible.

RESULTS OBTAINED

Calibration graphs were prepared from pure solutions using the stipulated procedure, and in all cases Beer's Law was obeyed up to the limits required. The calibration points were repeatedly checked and found to coincide with the original values. A number of mixed solutions containing known amounts of aluminium and iron in varying ratios were prepared and analysed by the ferron method. Results are shown in Table I.

TABLE I.—ANALYSIS OF ALUMINIUM-IRON SOLUTIONS BY THE FERRON METHOD

Present		Found	
Aluminium (as Al_2O_3) mg.	Iron (as FeO) mg.	Aluminium (as Al_2O_3) mg.	Iron (as FeO) mg.
0·038	0·129	0·038	0·128
0·076	0·103	0·074	0·102
0·111	0·077	0·111	0·077
0·151	0·052	0·152	0·054
0·189	0·026	0·186	0·025
0·038	0·180	0·038	0·180
0·189	0·077	0·189	0·079
0·095	0·064	0·098	0·065

Having thus established the reliability of the methods for pure solutions, several oxide residues were examined spectrographically and were found to contain in addition to the elements sought, small amounts of nickel, chromium, magnesium and traces of titanium and copper. These elements did not interfere with the

Continued on page 270

The Development of a Strain-or Displacement-Actuated Electronic Trigger for High-Temperature Stress-Relaxation Testing and Other Purposes*

By D. C. Herbert, B.Sc.(Eng.), G.I.Mech.E.† and D. J. Armstrong, G.I.Mech.E.‡

(Communication from The National Physical Laboratory)

The article describes the development of a displacement-actuated electronic trigger for stress-relaxation testing at high temperatures. Certain steps have been taken to ensure long life for the apparatus with the minimum of maintenance and special equipment. The importance of temperature control of the specimen is stressed and the measures necessary to overcome errors from this cause are mentioned. Apart from the specific requirements for stress-relaxation testing the paper mentions other applications needing a trigger actuated by small displacements.

THIS article describes an electro-mechanical system developed specifically for stress-relaxation testing; a brief introduction is therefore included explaining in rough outline the nature of the problem arising in certain high-temperature designs and the kind of test carried out to provide the necessary data. Servo control systems may be devised working on the same principle and using the same electronic equipment, e.g. in controlling temperature or fluid pressure by means of a dial indicator fitted with electrical contacts and in controlling industrial process machinery in workshops and factories by means of displacement-actuated contacts.

The Nature of the Stress-Relaxation Test

The design of components operating at high temperature frequently requires a knowledge of stress-relaxation data from tests conducted at the operating temperature under imposed strains which are maintained constant within extremely small limits over long periods. A bolted assembly, such as a steam pipe flange joint, consists of such components. The bolts are, in practice, tightened cold to a strain often taken as 0·0015 which corresponds, in the case of a ferritic steel, with a cold stress of 20 tons/sq. in. When heated to temperatures of 950°–1,050° F. the strain (after taking into account thermal expansion, change of elastic modulus and bedding down of the nut and its thread) probably has about the same value.

The stress relaxation test on a bolt material is made at the National Physical Laboratory by heating a standard creep test piece in a 5-ton creep machine to the operating temperature, applying the required total strain (say 0·0015), noting the corresponding initial load, then reducing this as creep occurs, by means of a servo-system, in such a way as to maintain the strain constant for periods of 1,000 or 2,000 hours. A typical curve obtained with the apparatus here described is shown in Fig. 1.

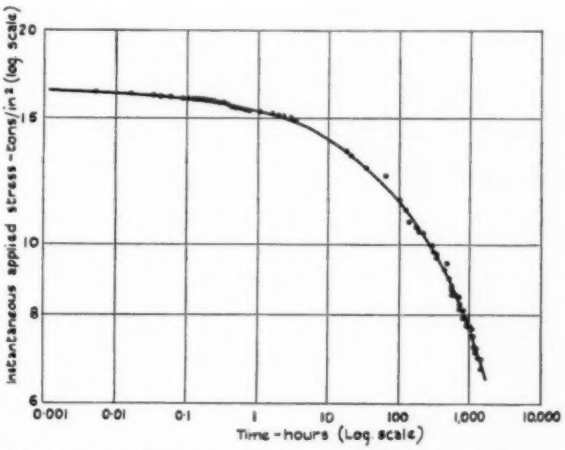


Fig. 1.—A typical stress-relaxation curve for a test at 500° C. from an initial strain of 0.0015.

Servo-systems for this purpose have been in use at the National Physical Laboratory for some years, but have suffered from a number of disadvantages not apparent in the new equipment. It was considered that a suitable system should make use of the equipment for creep testing existing at the National Physical Laboratory and should not require any extensometers other than those integral with the 5-ton creep machine. The apparatus should also be capable of being handled by junior laboratory staff and not require constant attention or maintenance. The system should adjust the load in very small steps, so as not to allow an error in the strain of discernible proportions (i.e., not much greater than 10^{-6}). It has been found that these requirements are met in practice.

The General Scheme of the Servo-System

The servo-system used in stress-relaxation testing is shown in Fig. 2. An N.P.L. extensometer is attached to the test piece; when creep occurs the two rhombs and mirrors rotate. A lightweight lever is attached to one

* tent Application No. 10921/51.
† perimental Officer, High Temperature Mechanical Properties Section, N.P.L.
‡ istant Experimental Officer, High Temperature Mechanical Properties tion, N.P.L.

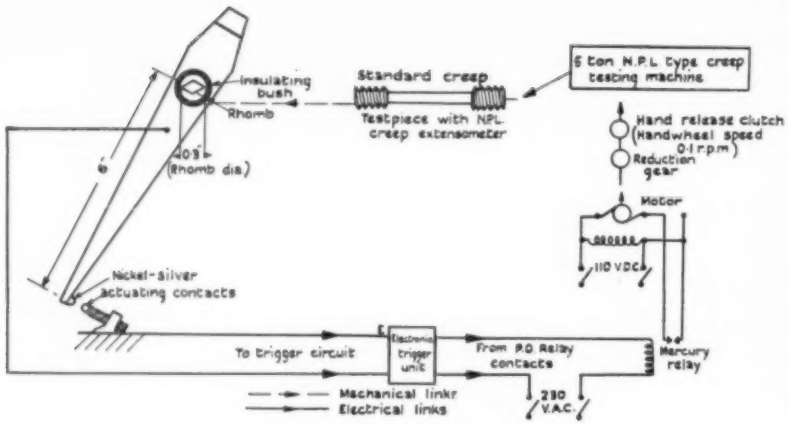


Fig. 2.—General scheme.

of the rhomb spindles and is insulated from it. (See photograph Fig. 3). Extension of the test piece causes the end of this lever to touch a fixed contact on the lower end of the extensometer, which sends a very small signal to the electronic trigger. This trigger amplifies the signal and closes the armature circuit of a continuously excited D.C. shunt motor, arranged to reduce the applied load by means of gearing to the handwheel of the machine. As soon as the original value of strain is reached by this reduction of load, electrical contact is broken and the loading gear comes to rest.

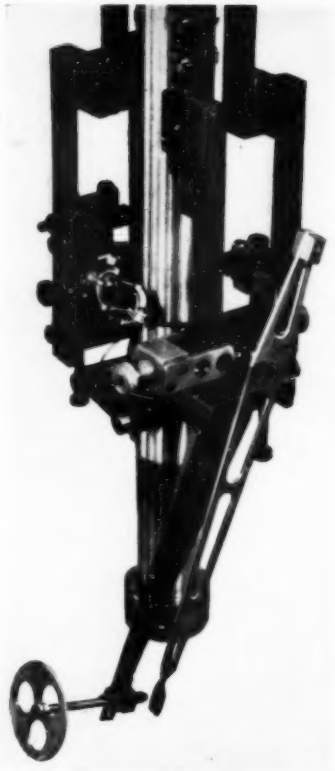


Fig. 3.—Standard N.P.L. type creep extensometer showing lightweight lever attachment.

Sensitivity of Contacts

To correct the load in very small steps, this cycle of events must take place for a test piece strain of about 10^{-6}. For the normal test piece of 0·564 in. diameter and gauge length 5 in., a rhomb of diameter 0·300 in. and a contact lever 6 in. long, the contact must actuate the trigger circuit for a displacement of :—

$$10^{-6} \times 5 \times 6/0{\cdot}300 = 10^{-4} = 0{\cdot}0001 \text{ in.}$$

It has been confirmed by direct measurement with a microscope, and by calculation from observed test piece strains, that the performance is in fact better than required.

The trigger circuit does not require special contacts : those in use are standard nickel-silver. No deterioration of the contacts occurs and no protection is required under normal conditions as the current to be broken is only a few micro amperes. The voltage across the contact gap is limited to 3 volts from a dry battery, so avoiding electrostatic* interference with the lightweight lever present when high voltages are used.

The trigger circuit is required to operate from an intermittent (on-and-off) signal of very low value amplified sufficiently to switch a motor starter without appreciable time delay. Operation must not be affected by mains voltage variations which may be wide under present-day conditions.

The circuit is based on the well-known Schmidt Trigger, the complete wiring diagram being given in Fig. 4. The double triode (6SN7) is used as the control valve. The plate and second grid voltages are obtained from a half-wave rectifier supply stabilised by two neon tubes (VR 150). A metal rectifier is preferred for long life but these are difficult to obtain at the present time so that a valve may be substituted (5V4G). The stability of the output voltage (using a valve rectifier in the manner described) is such that a voltage of 145 ± 1 is obtained for any input in the range 325 volts to 465 volts (D.C.).

The first grid is supplied from an external low voltage source, which is shorted through a high resistor in order to change the grid voltage sufficiently to produce the required triggering action of the second plate and the telephone relay. The relevant particulars for the circuit in Fig. 4 are : a 3-volt dry-battery in series with a 10,000-ohm resistor "shorted" by a switch current of 300 microamperes. The value of the series resistor may be as high as 1 megohm and thus the current only 3 microamperes with the same battery. No advantage would be gained in the present system, as the switch contacts operate satisfactorily at the higher level, and a slight time delay is avoided. Lower external voltages may be applied with slight modification of the resistor values determining the grid and plate voltages, but complete data on this aspect is not available. A 10,000-ohm resistor has been connected in series with the telephone relay as it has been found to remove the inductive effect otherwise present. An indication of the state of the battery and a check on the operation of the trigger may be obtained by switching off the D.C. motor supply and depressing the "Test" switch shown in Fig. 4.

* In this connection it is important to note the opinion of H. A. Thomas[1] (1947) that electrostatic attraction prevents the effective use of contact-displacement devices for precise control purposes. The instrument described is an exception to his rule.

1 Thomas, H. A., "Industrial Application of Electronic Techniques," *J. Inst. Elec. Engrs.*, 1947, **94**, Part I, 314–5.

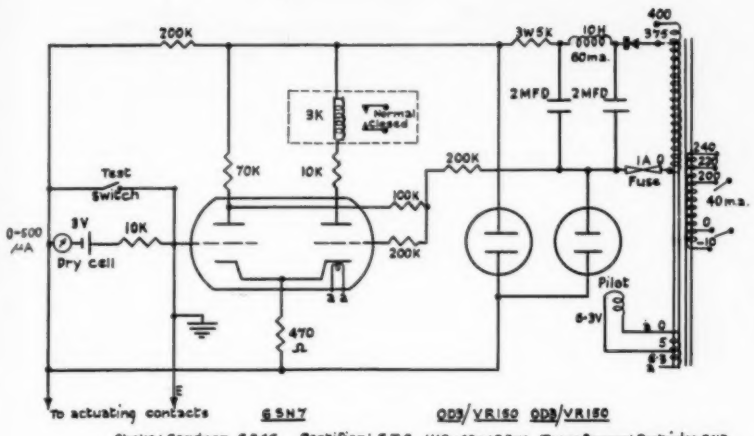


Fig. 4.—Trigger circuit.

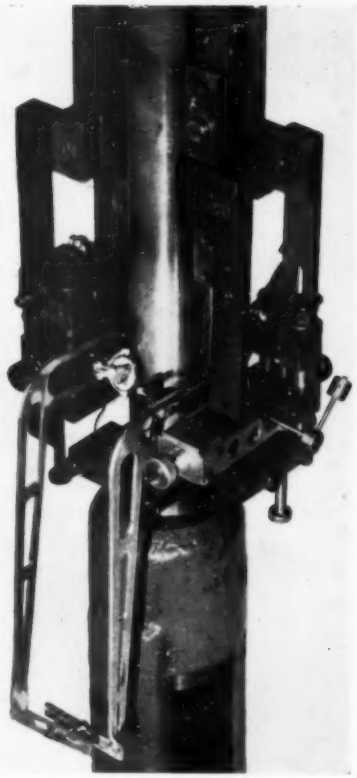


Fig. 5. — Alternative two lever contact.

The Motor Circuit and Gearing

The inertia of the whole system must be very low so that appreciable over-run does not occur, but at the same time a finite lag is necessary for stable control and to avoid chattering of the relays owing to too rapid operation.

In the stress-relaxation equipment these conditions have been met as follows. A light D.C. shunt motor is used with its field continuously excited, the switch opening and closing the armature circuit; the motor can be made to stop more quickly by connecting in a resistor in parallel with the armature so that magnetic braking is applied when the armature D.C. supply is switched off. The motor drives the testing machine loading gear through a robust worm reduction, all the links being free from back-lash.

Stable control is achieved by using a mercury-switch relay to switch the motor armature, this type of relay having a slight time-delay. The overall time-delay is still, however, small enough for the testing machine load to be adjusted by the automatic gear in steps as small as the reading accuracy of 1/1000th part of a ton.

Temperature Control

A most important factor in stress-relaxation testing is temperature control of the test piece and extensometers; this is especially so if automatic control of the stress is adopted. It is extremely difficult to control the test piece and extensometer temperatures to better than $\pm 0{\cdot}5^\circ$ C. over periods of testing of 1,000 hours or more, but these fluctuations are generally large enough to determine when the stress controller will operate. It is possible to have a difference of 10×10^{-6} per °C. between the linear coefficients of expansion of test piece and extensometer so that for a strain accuracy of 10^{-6} their temperatures must remain within $0{\cdot}1^\circ$ C. If a temperature change greater than this occurs, the load on the test piece will be removed in steps corresponding in amplitude with the temperature changes, and coinciding with either the maxima or minima of temperature according to the sign of the difference of coefficients. For practical purposes with control of $\pm 0{\cdot}5^\circ$ C. tests of 1,000 hours duration or longer are controlled better by hand operation at instants of correct temperature than by any automatic system which does not take into account temperature deviations, the automatic controller being retained for the first 1,000 or 2,000 hours.

Performance as a Stress-Relaxation Test Controller

To summarise the operation of the controller, it is only necessary to describe the procedure for starting a stress-relaxation test. The testing machine and its control equipment having been assembled, the test piece is brought to the required temperature for testing. The actuating contacts are set to operate at the required value of the test piece strain by setting back the rhomb and mirror using the extensometer in the normal way as in creep testing. It has been found possible to do this within 0·00001 strain, i.e. better than 1% of the total strain for most tests. After allowing temperature conditions to stabilise, the load is increased by hand until the indicating microammeter shows that contact is just being made. This corresponds to the maximum load, which is noted and the motor drive is then re-engaged by releasing the clutch. No further adjustments are necessary, the only work required being to take readings of load against time, at intervals of a few minutes at first, then every few hours, and after the second day readings are taken twice daily.

Some idea of the performance may be obtained by observing movements of the second rhomb. These should ideally record the same strain as the control rhomb. Therefore, the total strain upon loading indicated by this rhomb and its mirror should equal the amount the control rhomb was set back; there should be no change of reading of either mirror throughout the

test. In practice the uncontrolled mirror does generally change, but if the testing machine is properly aligned and the extensometers and test piece do not warp or bend, this change is small enough to be neglected. Thus, if the change in reading of the uncontrolled mirror in, say, 1,000 hours is equivalent to a strain of 10^{-5}, then this will correspond to a cumulative error totalling about 0·1 tons/sq. in. in the stress applied by the stress-controller; this error would be insignificant in a test initially started at 15 or 20 tons/sq. in. By using both rhomb-mirror assemblies as controllers (*i.e.* by using two moving contact arms moving apart or together as in photograph, Fig. 5) this error may be avoided, but the additional complication is generally an over-riding disadvantage.

Seven of the units described have been built and further units are under construction. Four units have each been in service for six months or more, on tests lasting 1,000 or 2,000 hours each. So far, only one dr battery has needed replacement, no other componen having required renewal or having given any kind of trouble. The actuating contacts have required no attention.

Acknowledgments

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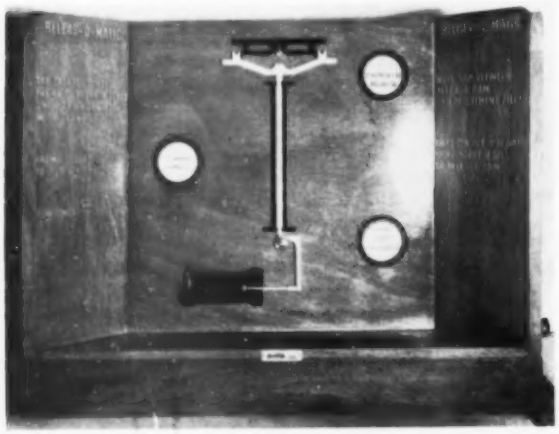
Seen at the Physical Society Exhibition

Dashpot-Controlled Balance Release Mechanism

AN interesting and important development demonstrated at the recent Physical Society's Exhibition was the Oertling Releas-o-Matic device. This is based upon a somewhat extensive research carried out in the Oertling laboratories to determine the main causes of loss of sensitivity in chemical and micro-chemical balances. The results have shown clearly how precision is adversely affected by blunting of the knives as a result of successive releases of the beam and how the initial fine edge can be maintained for a much longer period by reducing the velocity of impact of the knife-edge on the plane when the balance is set swinging.

Extensive laboratory tests involving several million weighing operations were made possible by a special device developed in the Oertling research laboratories and have demonstrated without question the practical advantages of the Oertling Releas-o-Matic device. It ensures automatically that the knife-edges make low velocity contact with the planes however the balance is released. The Releas-o-Matic device itself is essentially a simple mechanism embodying a precision carbon dashpot and piston mounted beneath the balance case. It requires virtually no adjustment, no maintenance, no lubrication and it is unaffected by temperature changes. It is claimed that the introduction of the Oertling Releas-o-Matic device represents a major advance in design of analytical balances, an advance comparable in importance with the earlier introduction of relieved knife-edges, now universally applied in precision balances.



A moving diagrammatical display of the principle of the Releas-o-Matic mechanism. The dashpot is a precision carbon assembly manufactured by the Morgan Crucible Co., Ltd.

An Absorptiometric Analytical Procedure

Continued from Page 266.

copper. These elements did not interfere with the determination of silica and manganous oxide. In the case of the ferron determination of ferrous oxide and alumina, all the interfering elements except titanium were eliminated in the preliminary ammonia separation. Although titanium was found to interfere with the estimation of alumina, the amounts present were found to be so small that their effect could be neglected. This titanium interference appeared to be linear and if necessary a correction graph could possibly be applied. Provision is made in the method for a further aliquot to be taken, on which the titanium content could be estimated.

Conclusions

The above work has shown that oxide residues which result from the chlorination of steel may be analysed quickly and accurately by routine staff, using absorptiometric techniques. The only element likely to be present which will interfere is titanium. At the titanium level normally present in these residues, the effect is small, and may be neglected.

Acknowledgment

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